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SILVER BOW CREEK

REMEDIAL INVESTIGATION WORK PLAN

SUBMITTED TO:

Solid Waste Management Bureau
Montana Department of Health and Environmental Sciences
Helena, Montana

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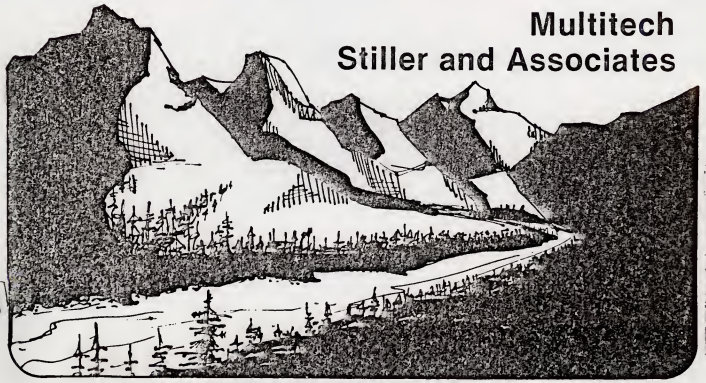

APR 1 4 1993

SILVER BOW CREEK REMEDIAL INVESTIGATION

WORK PLAN

Submitted To:

Solid Waste Management Bureau
Montana Department of Health and Environmental Sciences
Room B-201
Cogswell Building
Helena, Montana 59620

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August 1984

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EXECUTIVE SUMMARY

This report was prepared by MultiTech and Stiller and Associates for the Solid Waste Management Bureau (SWMB) of the Montana Department of Health and Environmental Sciences (MDHES) under Contract No. 40325-1202503. The contract requires MultiTech and Stiller and Associates to provide Remedial Investigation Support to MDHES for the Silver Bow Creek "Superfund" Site. This document is the fourth report required under the contract.

This Remedial Investigation Work Plan has been prepared to meet the following objectives:

- Describe the recommended work plan in detail.
- Describe the rationale for the proposed work plans, identifying what the data gaps are, and how the new data will describe the extent and severity of problems on Silver Bow Creek and aid in evaluating potential remedial technologies.
- Provide documenting and supporting material for the information presented.

Research for this report included review of published and unpublished reports plus personal communications. No field work was performed.

The RI/FS process applied to Silver Bow Creek will lead to the identification of conceptual plans for alleviating problems found within the study site. The Remedial Investigation described in this report will produce data that will be used to: 1) identify and describe in detail the specific problem areas within the site, and 2) evaluate and identify feasible remedial actions.

Five geographic areas were identified for use in describing the proposed investigations. These areas were selected for their commonality in problems, ground water characteristics, and surface water characteristics. The five areas are:

1. Summit Valley to Whiskey Gulch;
2. Whiskey Gulch to Head of Canyon;
3. Head of Canyon to Warm Springs Ponds;
4. Warm Springs Ponds; and
5. Upper Clark Fork River to points downstream (downstream limits vary according to discipline-specific requirements).

Specific investigations recommended are:

- Surface Water Investigation;
- Ground Water and Tailings Investigation;
- Point Source Investigation;
- Vegetation Mapping and Report;
- Waterfowl Investigation;

- Algal Investigation;
- Macroinvertebrate Report;
- Warm Springs Ponds Fish Tissue Study;
- Bioassay Study;
- Agricultural Investigation; and
- Warm Springs Ponds Life Span Study.

These studies and investigations are described in detail as to sampling locations, sampling times, sample analysis, data analysis, and reporting requirements.

The rationale for recommending specific investigations are presented. The major rationale for the proposed surface water, ground water, tailings, and point source investigations is the lack of adequate data to accurately identify problem areas and evaluate potential remedial actions. Biological investigations are recommended to aid in describing the extent and severity of the problems and because biological systems are potential pathways for human exposure to the contamination present in Silver Bow Creek and the Upper Clark Fork River.

Supporting material backing up rationales or proposed investigations are in the Appendix.

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1.0 INTRODUCTION

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA - P.L. 96-510) requires the U.S. Environmental Protection Agency (EPA) to identify, list, investigate, and cleanup non-controlled hazardous waste sites not regulated by the Resource Conservation Recovery Act (RCRA - P.L. 94-580) of 1976 or the Toxic Substances Control Act (TOSCA - P.L. 94-469). CERCLA allows the EPA to enter into cooperative agreements with the states to administer the "Superfund" program within a state. Montana has entered into such a Cooperative Agreement with the EPA for the Silver Bow Creek "Superfund" site. The state agency responsible for administering this program is the Solid Waste Management Bureau (SWMB) of the Montana Department of Health and Environmental Sciences (MDHES).

This report was prepared by MultiTech and Stiller and Associates for the SWMB of the MDHES under Contract No. 40325-1202503. This contract requires MultiTech and Stiller and Associates to provide Remedial Investigation Support to the SWMB/MDHES for the Silver Bow Creek "Superfund" site.

The objectives of the Investigation Program are:

- Identify potential remedial actions for "cleaning up" the Silver Bow Creek site and the data necessary to evaluate the potential actions.

- Develop a work plan to guide field studies that produce the data requisite for assessing the extent and severity of contamination in the Silver Bow Creek-Upper Clark Fork system and evaluating potential remedial actions.

- Develop a Quality Assurance Plan that will ensure the integrity of data collected during the field studies.

- Develop a Health and Safety Plan that protects remedial investigation workers, remedial action workers, and the general public.

- Develop a site map that can be used for showing proposed sampling sites and project locations.

This report was prepared by MultiTech and Stiller and Associates to guide field studies that will produce data for: 1) assessing the extent and severity of contamination in the Silver Bow Creek-Upper Clark Fork system; and 2) evaluating potential remedial action.

This report has been organized to meet the following objectives:

- Describe the Remedial Investigation/Feasibility Study (RI/FS) process;

- Describe the proposed work plans; and

- Describe the rationale for recommending the specific study plans contained within this report.

This report will be used by the SWMB/MDHES to guide the Remedial Investigation. Section 2.0, Work Plans, will be used as the scope-of-work by the contractor performing the remedial investigation phase of the project.

1.1 CONCEPTUAL PLAN

The Remedial Investigation of the Silver Bow Creek "CERCLA Site" must meet two separate but complementary objectives. These objectives are:

- Develop data, that in conjunction with existing data, can be used to describe the extent and severity of contamination of Silver Bow Creek and the Upper Clark Fork River. This data will be used for the performance of an endangerment assessment, the final step of the Remedial Investigation.
- Develop data, that in conjunction with existing data, can be used to evaluate, select, and design remedial alternatives.

These objectives are necessary to the Remedial Investigation because the ultimate aim of the "Superfund" program is the clean-up of uncontrolled hazardous waste sites. The Remedial Investigation of

Silver Bow Creek is one step of a several step process leading towards Remedial Actions. This process is illustrated in Figure 1-1.

As seen in Figure 1-1 the Silver Bow Creek Site was listed by the Environmental Protection Agency (EPA) as an uncontrolled hazardous waste site in December of 1982. Following the listing, a Remedial Action Master Plan (RAMP) was completed by CH_2M Hill under contract to EPA in March of 1983. The RAMP outlined the process leading to remedial actions and proposed specific remedial investigations. In October of 1983 the EPA and the Solid Waste Management Bureau of Montana's Department of Health and Environmental Sciences (SWMB/MDHES) signed a cooperative agreement on the Silver Bow Creek site giving primary jurisdiction for addressing site problems to the State of Montana.

The State initiated Remedial Investigation support activities following the cooperative agreement and in February of 1984 contracted MultiTech and Stiller and Associates to develop five documents to guide the Remedial Investigation. These five documents are shown on Figure 1-1 below the box labelled investigation support.

The next step following completion of the Remedial Investigation support activities will be the performance of the Remedial Investigation. These field studies will most likely take up to 12 months to complete and should begin sometime in the early Fall, 1984. Following completion of the Remedial Investigation, including the Investigation Report, a Endangerment Assessment will be performed.

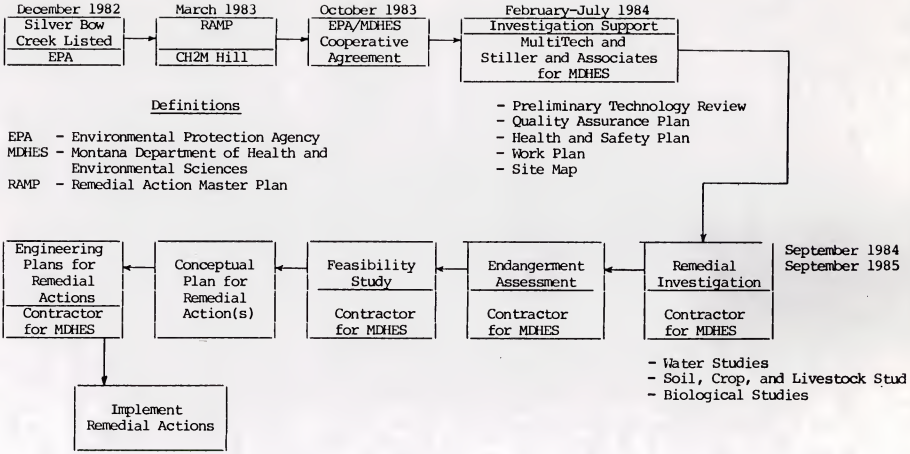


FIGURE 1-1.—SILVER BOW CREEK REMEDIAL INVESTIGATION PROCESS

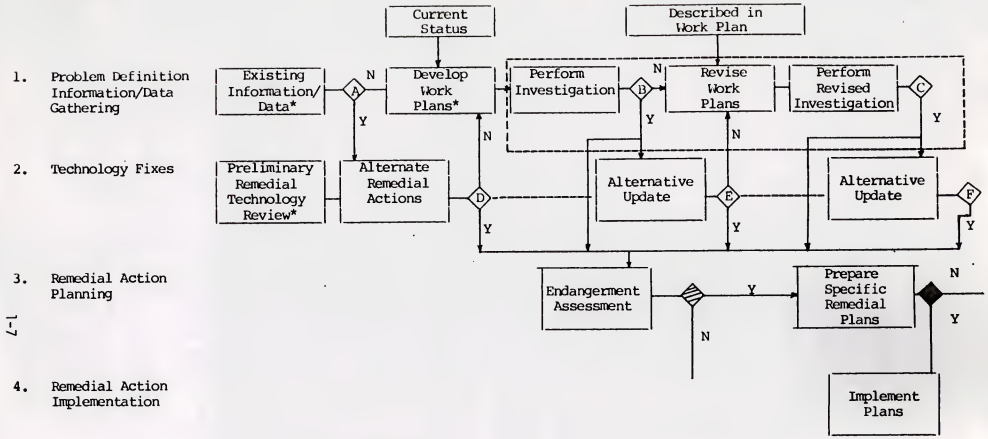
Depending on the results of the Endangerment Assessment, the next step would be Feasibility Studies. These studies , which whould begin following the completion of the Endangerment Assessment, will evaluate alternative remedial actions and identify those actions that should be implemented.

In order for the work plans for the Remedial Investigation to meet the two objectives listed above, their development should take into account three major issues:

- What are the major problems on Silver Bow Creek?
- What are the potential technology fixes (remedial actions) for correcting problems on Silver Bow Creek? and
- What data currently exists and is it useful for defining the problems and evaluating remedial actions?

Planning for the Silver Bow Creek Remedial Investigation has followed an integrated process to address these three issues. A flow diagram illustrating the overall Remedial Action planning is shown in Figure 1-2.

Remedial investigation planning work which has been completed is indicated by a single asterisk (*) in the appropriate boxes in Figure 1-2. The preferred path for the development of remedial actions is one in which the decision at point B (Figure 1-2)



*Indicates Remedial Investigation Work Completed

◇ Decision Point - Enough information to: 1) describe problems 2) perform endangerment assessment and 3) evaluate alternative remedial actions

◆ Decision Point - Cost effective?

▨ Decision Point - Human health and welfare endangered?

FIGURE 1-2.—DIAGRAM ILLUSTRATING REMEDIAL ACTION PLANNING PROCESS

is that enough data exist to evaluate and choose the alternatives. In order to remain flexible, however, the Remedial Investigation planning may have to be updated as appropriate to incorporate new findings. The process past decision point B (as shown in Figure 1-2) is illustrated to show how flexibility can be built into the program.

1.2 DEFINITION OF GEOGRAPHIC INVESTIGATION UNITS

1.2.1 Rationale

Evaluation of the problems along Silver Bow Creek and data collected to date indicate that the study area can be divided into discrete geographic areas on the basis of the types and distribution of the problems, as well as on the basis of demonstrable hydrologic boundaries. Accordingly, the study area is divided into five such sub-areas.

Several benefits of making this division are:

1. It allows examination of specific problem sites within the context of discrete stream reaches. This permits an individual site's impact(s) to be evaluated along a given stream reach, as well as over the entire study area.

2. By breaking the study area into discrete sub-areas and examining site-specific impacts accordingly, remedial

alternatives and subsequent engineering designs will be more readily prepared and better accomplished. Area boundaries are shown in Figure 2-2.

1.2.2 Description of Area Limits and Similarities

The study area is divided into five geographic sub-areas. The limits of the five units and the general nature of problems identified to date are described in Table 1-1.

The study area extends from the Continental Divide above the Berkeley Pit down Silver Bow Creek and the Clark Fork River to just north of Deerlodge, Montana. Because the focus of the proposed Remedial Investigation is on Silver Bow Creek, tributaries and headwaters of Silver Bow Creek are not included in the study area other than to measure their influences on Silver Bow Creek at their mouths.

Mill tailings deposits are known to exist along the Clark Fork River below Deer Lodge, and their potential effect on the river is of concern to Montana Department of Fish, Wildlife, and Parks (Phillips, 1984).

1.3 PROJECT SCHEDULE

Figure 1-3 shows the proposed schedule for the implementation of the Silver Bow Creek Remedial Investigation identified by task

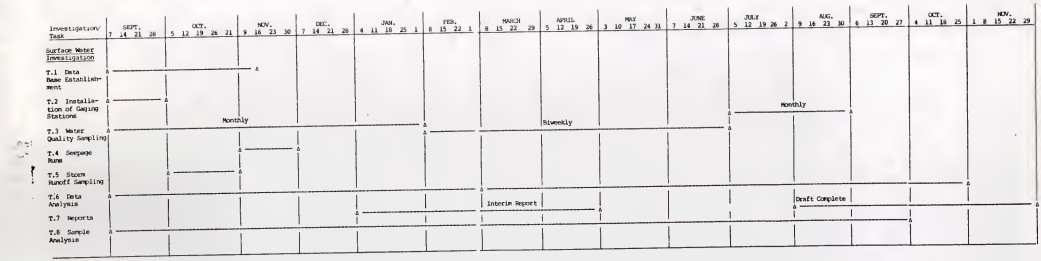
for each investigation. Figure 1-4 shows the path of information flow required during the Remedial Investigation.

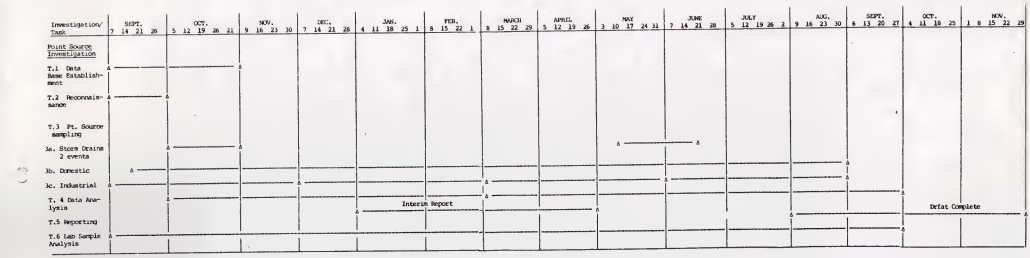
TABLE 1-1.--DESCRIPTION OF AREA LIMITS AND PROBLEMS
See Exhibit 1

Area Designation	Area Limits	Known Problems
I	Area I extends from the Continental Divide to and including the confluence of Whiskey Gulch with Silver Bow Creek.	The majority of point discharges to Silver Bow Creek occur in this reach. Also, the greatest proportion of the study area population lives in this reach. Ground water degradation also exists.
II	Area II extends from below the Silver Bow Creek confluence with Whiskey Gulch to the head of Silver Bow Creek Canyon, approximately one and one-half miles below Miles Crossing.	Major deposits of abandoned mill tailings occur in this reach. Ground water degradation is documented. Several minor point discharges also exist.
III	Area III extends from the head of Silver Bow Creek canyon to just above the upper pH shack at AMC's Warm Springs Pond No.3, and includes Mill and Willow Creek drainages, and along the Mill-Willow By Pass west of the Warm Springs Ponds, to just above Warm Springs Pond 2 discharge.	Thinner, yet extensive deposits of mill tailings occur in this reach. Known or suspected irrigation problems associated with the tailings may exist. Minor point source discharges are known. Impacts on surface water quality from AMC's Opportunity and Warm Springs Ponds are suspected.

TABLE 1-1.--DESCRIPTION OF AREA LIMITS AND PROBLEMS (Continued)
See Exhibit 1

Area Designation	Area Limits	Known Problems
IV	Area IV encompasses AMC's Warm Springs Ponds	Warm Springs Ponds have complex chemical and biological problems which have only been partially documented.
V	Area V extends from the Mill-Willow By Pass above the Warm Springs Pond No. 2 discharge, and down the Clark Fork River to the Kohrs Bridge.	The remaining influences of AMC's Opportunity and Warm Springs Ponds discharge are relatively unknown. Minor point discharges occur, and thin tailings deposits exist along the floodplain.


Investigation/ Task
SEPT. 7 14 21 28
OCT. 5 12 19 26 21
NOV. 9 16 23 30
DEC. 7 14 21 28
JAN. 4 11 18 25 1
FEB. 8 15 22 1
MARCH 8 15 22 29
APRIL 5 12 19 26
MAY 3 10 17 24 31
JUNE 7 14 21 28
JULY 5 12 19 26 2
AUG. 9 16 23 30
SEPT. 6 13 20 27
OCT. 4 11 18 25
NOV. 1 8 15 22 29
Surface Water Investigation
T.1 Data Base Establishment
T.2 Installation of Gaging Stations
Monthly
Monthly
T.3 Water Quality Sampling
Biweekly
T.4 Seepage Runs
T.5 Storm Runoff Sampling
T.6 Data Analysis
Interim Report
Draft Complete
T.7 Reports
T.8 Sample Analysis


Investigation/ Task
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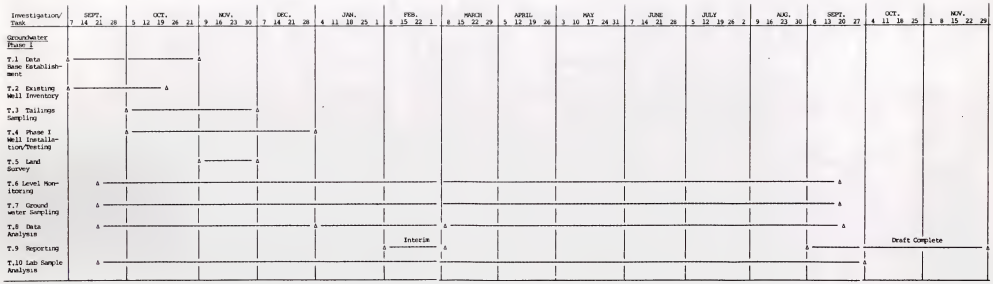
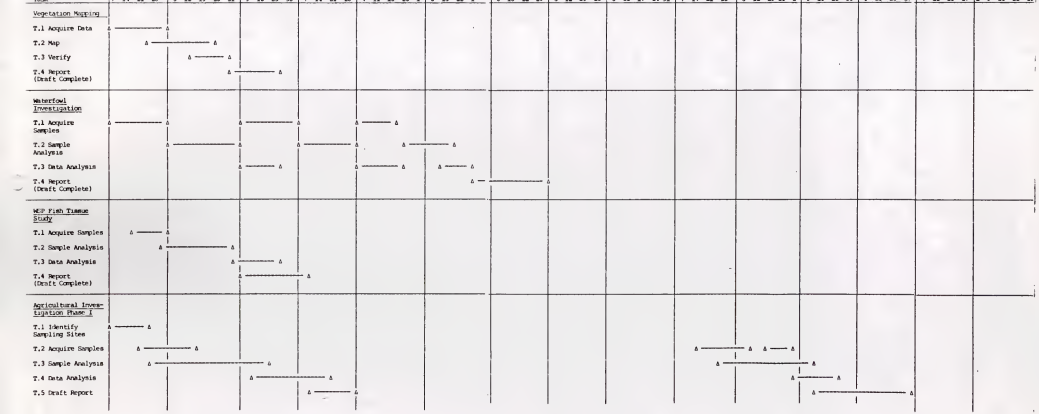
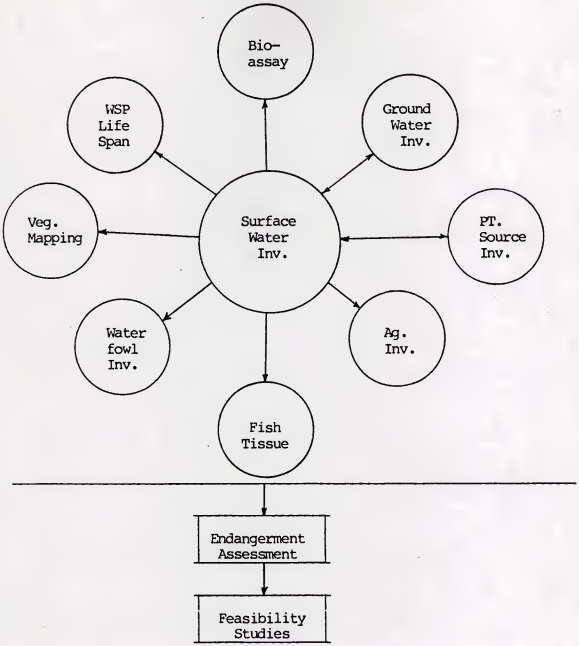
OCT. 5 12 19 26 21
NOV. 9 16 23 30
DEC. 7 14 21 28
JAN. 4 11 18 25 1
FEB. 8 15 22 1
MARCH 8 15 22 29
APRIL 5 12 19 26
MAY 3 10 17 24 31
JUNE 7 14 21 28
JULY 5 12 19 26 2
AUG. 9 16 23 30
SEPT. 6 13 20 27
OCT. 4 11 18 25
NOV. 1 8 15 22 29
Point Source Investigation
T.1 Data Base Establishment
T.2 Reconnaissance
T.3 Pt. Source sampling
3a. Storm Drains 2 events
3b. Domestic
3c. Industrial
T. 4 Data Analysis
Interim Report
Draft Complete
T.5 Reporting
T.6 Lab Sample Analysis


Investigation/ Task
SEPT. 7 14 21 28
OCT. 5 12 19 26 21
NOV. 9 16 23 30
DEC. 7 14 21 28
JAN. 4 11 18 25 1
FEB. 8 15 22 1
MARCH 8 15 22 29
APRIL 5 12 19 26
MAY 3 10 17 24 31
JUNE 7 14 21 28
JULY 5 12 19 26 2
AUG. 9 16 23 30
SEPT. 6 13 20 27
OCT. 4 11 18 25
NOV. 1 8 15 22 29
Groundwater Phase I
T.1 Data Base Establishment
T.2 Existing Well Inventory
T.3 Tailings Sampling
T.4 Phase I Well Installation/Testing
T.5 Land Survey
T.6 Level Monitoring
T.7 Ground water Sampling
T.8 Data Analysis
T.9 Reporting
T.10 Lab Sample Analysis
Interim
Draft Complete


Investigation/ Task
SEPT. 7 14 21 28
OCT. 5 12 19 26 21
NOV. 9 16 23 30
DEC. 7 14 21 28
JAN. 4 11 18 25 1
FEB. 8 15 22 1
MARCH 8 15 22 29
APRIL 5 12 19 26
MAY 3 10 17 24 31
JUNE 7 14 21 28
JULY 5 12 19 26 2
AUG. 9 16 23 30
SEPT. 6 13 20 27
OCT. 4 11 18 27
NOV. 1 8 15 22 29
Vegetation Mapping
T.1 Acquire Data
T.2 Map
T.3 Verify
T.4 Report (Draft Complete)
Waterfowl Investigation
T.1 Acquire Samples
T.2 Sample Analysis
T.3 Data Analysis
T.4 Report (Draft Complete)
MDP Fish Tissue Study
T.1 Acquire Samples
T.2 Sample Analysis
T.3 Data Analysis
T.4 Report (Draft Complete)
Agricultural Investigation Phase I
T.1 Identify Sampling Sites
T.2 Acquire Samples
T.3 Sample Analysis
T.4 Data Analysis
T.5 Draft Report

Investigation/ Task	SEPT. 7 14 21 28	OCT. 5 12 19 26 21	NOV. 9 16 23 30	DEC. 7 14 21 28	JAN. 4 11 18 25 1	FEB. 8 15 22 1	MARCH 8 15 22 29	APRIL 5 12 19 26	MAY 3 10 17 24 31	JUNE 7 14 21 28	JULY 5 12 19 26 2	AUG. 9 16 23 30	SEPT. 6 13 20 27	OCT. 4 11 18 25	NOV. 1 8 15 22
Bioassay															
T.1 Chronic Flow Through Test															if selected
T.2 Viable Gamete Study (Phase II)										Chronic Flow Through					
T.3 Report Preparation (Draft Complete)															
Warm Springs Pond Life Span Study															
T.1 Bathymetric Survey															
T.2 Sediment-Precipitate Sampling															
T.3 Data Evaluation															
T.4 Report (Draft Complete)															
QA/QC															
T.1 Data Management															
T.2 QA/QC Reports															
T.3 QA/QC Sample Analysis															
Health and Safety															
T.1 H & S Briefing															
T.2 H & S Audit															
T.3 H & S Reporting															

FIGURE 1-4 SILVER BOW CREEK REMEDIAL INVESTIGATION INFORMATION FLOW



2.0 WORK PLAN

Section 2.0 of this document describes the studies required to develop new data on Silver Bow Creek, the Warm Springs Ponds, and the upper Clark Fork River that will meet the objectives of the Remedial Investigation. These objectives are:

- To develop new data that, in conjunction with existing data, can be used to describe the extent and severity of contamination of surface and ground water in the vicinity of Silver Bow Creek and the upper Clark Fork River; and,

- To develop new data that, in conjunction with existing data, can be used to evaluate and compare potential remedial actions.

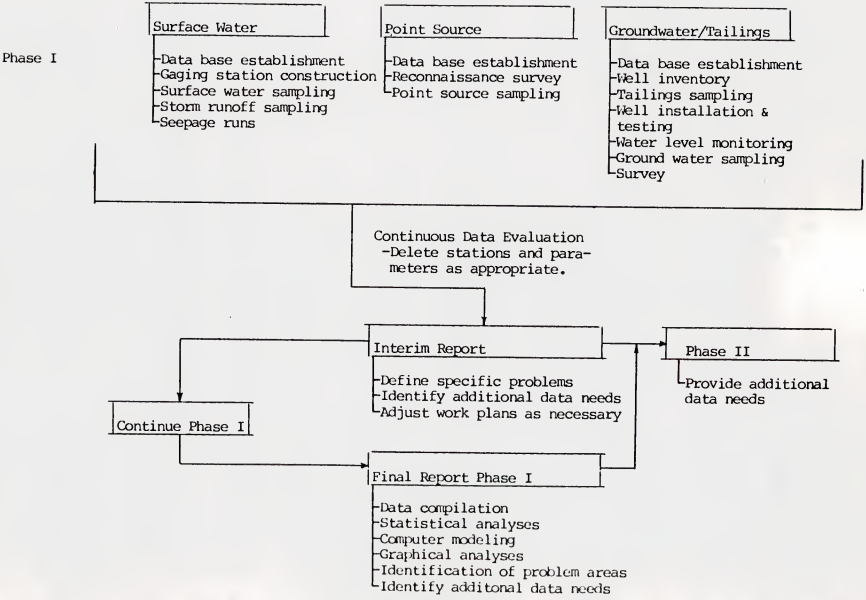
Studies are described for:

- Hydrologic Investigations;
- Biological Investigations; and
- Environmental Engineering Investigations.

2.1 INTRODUCTION TO HYDROLOGICAL SCIENCES WORK PLAN AND CONCEPTUAL APPROACH

Figure 2-1 exhibits the outline of the Remedial Investigation's Hydrological Sciences Work Plan. The work plan is to be completed

FIGURE 2-1.-SCHEMATIC OF HYDROLOGIC SCIENCES WORK PLAN



in two overlapping phases, the results of the first phase defining part of the scope for the second. Analysis and evaluation of all data and preparation of draft and final project reports will occur as data needs are met.

Phase I will be completed over the initial four to twelve months of the Remedial Investigation. Phase II will commence when enough data generated by the first phase is available for decisionmaking and will continue until all field work required of the Remedial Investigation is complete. An understanding of the system is necessary to the eventual identification of specific, appropriate remedial measures. It is anticipated that the Hydrological Sciences Work Plan will be initiated in late summer or early fall of 1984.

The Hydrologic Sciences Work Plan combines all aspects of the ground water, surface water, point source discharge, and tailings investigations. These tasks are combined because of obvious and demonstrable interrelationships among the topics.

Phase I of the Hydrological Sciences Work Plan contains three components: start-up of a one-year comprehensive surface water and point source discharge sampling program; sampling and inventorying of tailings; and, installation of the initial shallow ground water and tailings hydrochemical monitoring systems.

Initiation of a comprehensive surface water and point source discharge sampling program is premised on the fact that Silver Bow Creek and its continuation, the Clark Fork River, are the central hydrologic features within the study area. It is the area's master stream system; all other drainages are tributary to it. The streams are also closely interconnected with the area's shallow ground water systems and either serve as recharge sources for these systems, or as discharge area for them. Consequently, a comprehensive analysis of the flow and quality of the streams is a necessary step in defining the severity and extent of contaminated waters.

Concurrent with initiation of a comprehensive surface water and point source discharges sampling program are necessary inventories and representative sampling of all mill tailings and mine wastes in the study area.

The third component of Phase I includes preliminary determinations of ground water flow directions, installation of several ground water observation wells or piezometers in specific, key locales, and initial sampling for ground water quality from selected wells. Also included is installation of the tailings hydrochemical monitoring system. Because chemical reactions taking place in the tailings are related to seasonal fluctuations in the water table, adequate data are essential to an understanding of these processes.

Preliminary data evaluation and interim reports on the first four to six months of Phase I activities will be performed. Objectives and activities of this evaluation will be:

- To define the severity and extent of specific problem sites or areas where data are sufficient to do so. These sites or areas will then be "set aside" until remaining studies are completed. Such sites or areas will be ready for remedial technology review or engineering feasibility studies, if desired;

- To delete surface water, point source, or ground water sampling sites where no problems are identifiable or suspected;

- To adjust, as necessary, parameter lists for continuing Phase I water quality sampling where it can be shown that Phase I activities have identified new problems or indicated cause for a lessening of concern in specific instances; and,

- To define the continuation and possible expansion of the investigations, based upon data obtained during Phase I. This additional work is labeled as Phase II.

Phase II of the Hydrological Sciences Work Plan (Figure 2-1) is the investigative activities identified as needed by the Phase I investigations.

As appropriate final data analysis and evaluation will be initiated. Appropriate methodologies will be utilized to evaluate all data to achieve the primary objectives of the Remedial Investigation. Draft and final project reports will be prepared subsequent to these analyses and as integral components of the Remedial Investigation.

All data generated by the hydrological sciences work plans will be transmitted to the MDHES and EPA in hardcopy form and on STORET compatible 9 track tapes.

2.1.1 Surface Water Work Plan

The initial and central focus of the Surface Water Work Plan is the detailed characterization of surface water quality and quantity in the study area. The work plan is presented as two phases. The first phase is both intensive and extensive, with the stated objectives being to:

- Determine the spatial and temporal variations in surface water quality and quantity;
- Determine the most affected stream reaches and those sources

or mechanisms within the reaches causing water quality degradation;

- Determine how stream water quality changes during major precipitation runoff events; and,

- Determine how stream water quality changes in response to ground water discharge.

The Surface Water Work Plan is designed to provide indications as to which processes described in Section 3.1.4 are the most significant contributors to water quality degradation. It is for this reason that most surface water quality samples will be analyzed for total and dissolved fractions of selected metals. Changes in timing and relative concentrations of many constituents vary with runoff hydrographs because of the process by which they are introduced to the surface water system.

The second phase of this portion of the Remedial Investigation is a continuation of activities described for Phase I. Adequate flexibility to the work plan is allowed in Phase II so that necessary adjustments can be made to complete field work in a timely and effective manner.

2.1.1.1 Task 1 - Data Base Establishment

All surface water flow and quality data will be reviewed for accuracy and relevance and compiled into a master project file. The master project file will be a computerized data management system capable of storing and recalling significant amounts of data, as well as extracting selected data for specific graphical, numerical, or statistical analyses.

Suspect data as established by screening with U.S. EPA criteria for data acceptance on "CERCLA" projects, will be used as appropriate. Data collected by means other than the investigation's QA/QC plan or one of comparable rigor, will not be used, under normal conditions, for anything other than to provide background or planning information for the investigation team.

2.1.1.2 Task 2 - Installation of Permanent Gaging Stations

Area I

Three permanent USGS gaging stations are located in Area I. These stations include SS-01, SS-02 and SS-07 (See Figure 2-2). Negotiations will be conducted with the USGS such that all flow records will be made available in a timely fashion and utilized in the surface water investigation. As well, water quality data collected by MBMG at these sites will be obtained and used as appropriate.

One additional permanent gaging station (Station SS-03, Figure 2-2) will be installed in the vicinity of the Kaw Avenue Bridge near the mouth of the Butte Metro Storm Drain. Gaging station SS-03 will consist of a flume capable of measuring flows ranging from 0.1 to 10 cubic feet per second (cfs). The flume will be equipped with a continuous recorder. Details regarding flumes are contained in Section 4.4.4.6, Calibrated Control Structures. Maintenance plans for continuous recorders are contained in the QA/QC Plan (Section 6.1).

Area II

One permanent continuously recording gaging station will be constructed in Area II (station SS-14, Figure 2-2). The gaging station will be of the stage-discharge variety and will be constructed and calibrated according to details outlined in Section 4.4.4.5. Maintenance objectives for stage-discharge gaging stations are detailed in the QA/QC Plan (Section 6.1).

Area III

A permanent stage-discharge gaging station (SS-17) will be constructed either near the highway 10-A bridge or near the Stewart Street Bridge (Figure 2-2). This station will be constructed, operated, and maintained in accordance with specifications outlined in Section 4.4.4.5.

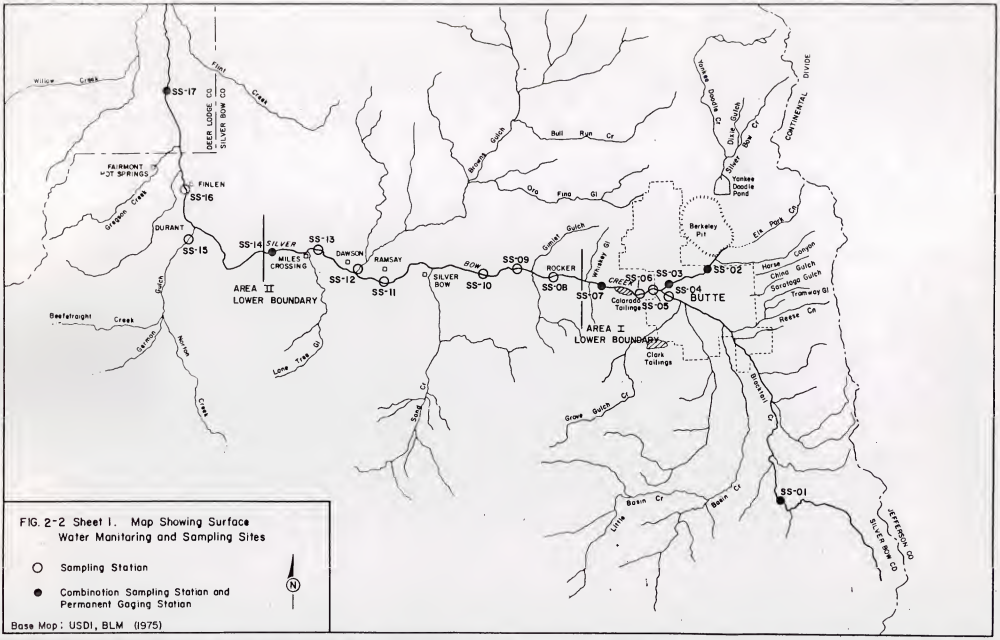
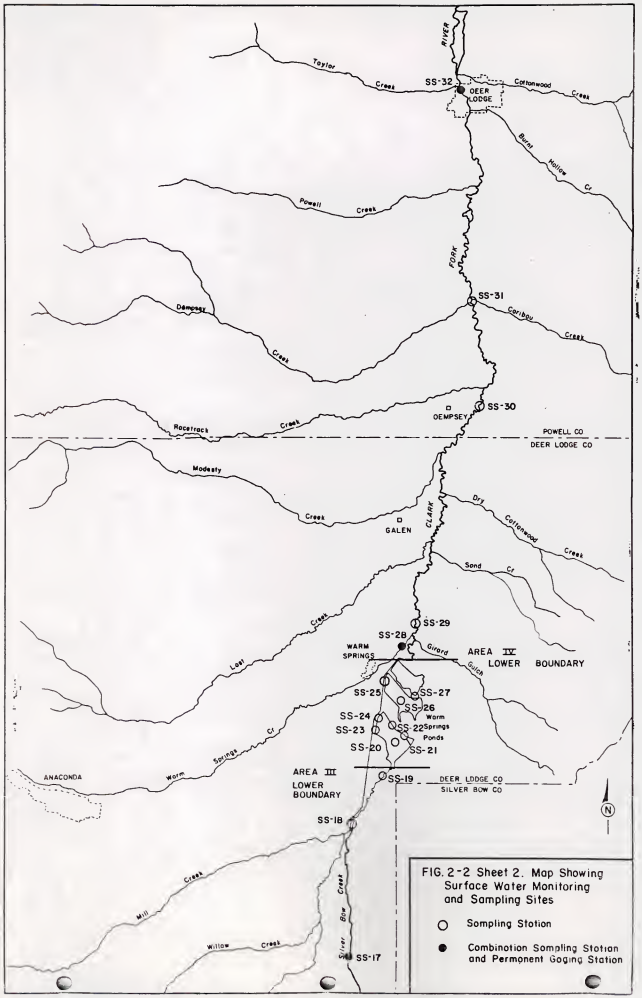


FIG. 2-2 Sheet 1. Map Showing Surface Water Monitoring and Sampling Sites

○ Sampling Station

● Combination Sampling Station and Permanent Gaging Station

Base Map: USDI, BLM (1975)


Taylor Creek
SS-32
DEER LODGE
Cottonwood Creek
Burns Hollow Cr
Powell Creek
FORK
SS-31
Caribou Creek
Dempsey Creek
OEMPSEY
SS-30
Racetrack Creek
POWELL CO
DEER LODGE CO
Modesty Creek
GALEN
CLARK
Dry Cottonwood Creek
Sand Cr
SS-29
SS-28
WARM SPRINGS
Girard Gulch
AREA IV LOWER BOUNDARY
Lost Creek
SS-25
SS-27
SS-26
Warm Springs Ponds
SS-24
SS-23
SS-22
SS-20
SS-21
Warm Springs Cr
ANACONDA
AREA III LOWER BOUNDARY
SS-19
DEER LODGE CO
SILVER BOW CO
SS-18
Mill Creek
Willow Creek
Silver Bow Creek
SS-17
N
FIG. 2-2 Sheet 2. Map Showing Surface Water Monitoring and Sampling Sites
Sampling Station
Combination Sampling Station and Permanent Gaging Station

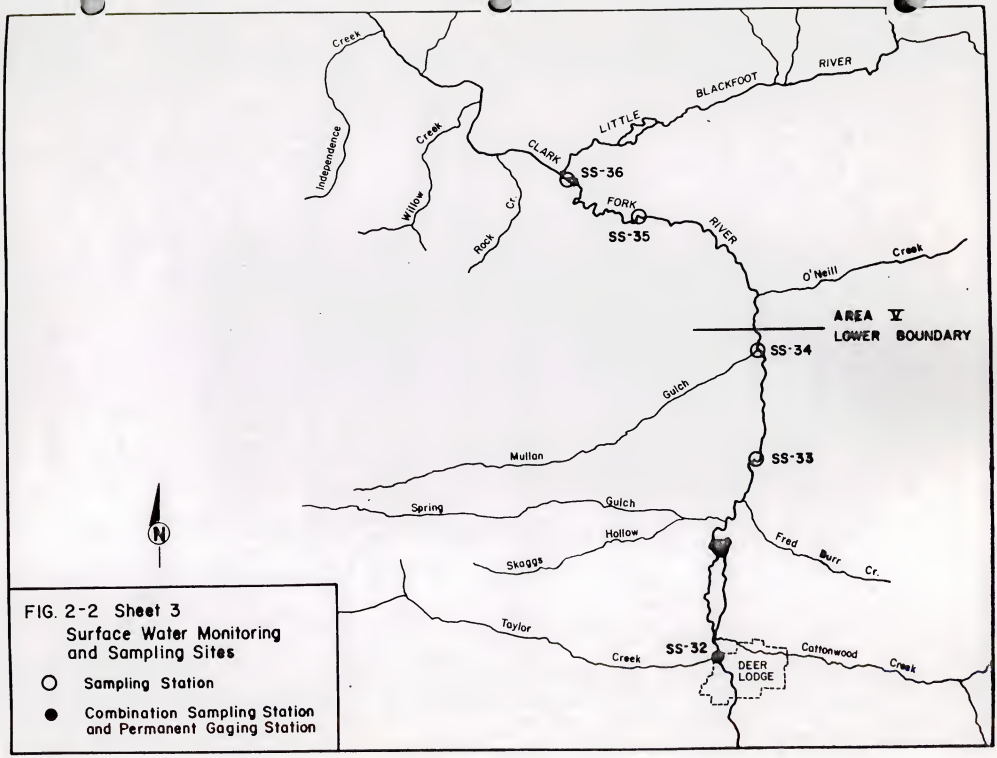


FIG. 2-2 Sheet 3
Surface Water Monitoring and Sampling Sites

○ Sampling Station

● Combination Sampling Station and Permanent Gaging Station

Area V

Two active USGS gaging stations are located in Area V: SS-28 (located near the mouth of Warm Springs Creek) and SS-32 (located near Deer Lodge) The locations of these gaging stations are shown on Figure 2-2. Flow data generated by these active USGS stations will be obtained and utilized.

2.1.1.3 Task 3 - Implementation of Water Quality Sampling Program

Area I

Area I surface water sampling sites are shown on Figure 2-2. The sampling sites will include permanent streamflow gaging sites described in Task 2, in addition to three other sites. These sites will include: Blacktail Creek near its mouth; Silver Bow Creek above a seep in the vicinity of the Montana Pole and Treating Plant; and Silver Bow Creek above the Colorado Tailings. Table 2-1 shows the types of sampling to be conducted, as well as the frequency with which sampling will be completed at these sites. Water quality parameters to be analyzed for various analytical categories are presented in Table 2-2. Measurement and sampling of bedload may be conducted at Silver Bow Creek sampling sites in accordance with procedures outlined in Section 4.4.4.3.

TABLE 2-1.-- AREA I - SURFACE WATER SAMPLING SITES, SAMPLING FREQUENCIES, AND SAMPLE PARAMETERS

SITE NO.[a]	SITE LOCATION	SAMPLE ANALYTICAL CATEGORY[b,c,d]
SS-01	USGS gaging station on Upper Blacktail Creek	I
SS-02	USGS gaging station at Texas Avenue	II + CN, O & G
SS-03	Gaging station at Kaw Avenue	II + CN, O & G
SS-04	Blacktail Creek at Mouth	II
SS-05	Silver Bow Creek above MP & T seep	II + CN, PCB
SS-06	Silver Bow Creek above Colorado Tailings	II + CN, PCB, PCP, O & G
SS-07	USGS gaging station below Colorado Tailings	II + CN, PCB, PCP, O & G

Notes:

a) Sample site locations shown on Figure 2-2.

b) Sample analyses parameter categories described in Table 2-2.

c) CN - cyanide; O & G - oil and grease; PCB - polychlorinated biphenyls; PCP - pentachlorophenol. Sampling for these parameters will be discontinued if initial analytical results fail to note their presence.

d) Sampling frequency, based on September, 1984 start-up, is monthly for all sample sites during the period September, 1984 through January, 1985 and July thru August, 1985 and bi-weekly for the period February, 1985 through June, 1985.

TABLE 2-2.-- SURFACE WATER AND POINT SOURCE SAMPLE PARAMETER LIST[a]

CATEGORY I: FIELD MEASUREMENTS

pH	Temperature
Specific Conductivity	Discharge

CATEGORY II: PARTIAL PARAMETER LIST; Includes parameters listed in Category I plus:

TDS (measured)	Copper[b]
TSS	Zinc[b]
Sulfate	Iron[b]
Nitrate	Lead[c]
Alkalinity	Arsenic[c]
Hardness	Cadmium[c]

CATEGORY III: COMPLETE PARAMETER LIST; Includes parameters listed in Categories I and II plus:

Ortho-phosphate
Phosphorous (total)

Notes:

[a]This list constitutes an initial parameter list only. If initial sample results do not provide reason to continue, subsequent sampling will be adjusted as appropriate. Such a change will be determined by the Remedial Investigation contractor in consultation with the MDHES project manager.

[b]Total and Dissolved Constituents

[c]Total Constituents

[d]A test will be conducted to evaluate total metals as defined by the QA Plan vs. total recoverable as performed by the DHES-WQB lab so that data comparisons can be made.

Area II

Area II sampling sites are shown on Figure 2-2. The sampling sites will include permanent streamflow gaging stations described in Task 2, in addition to the following sites: Silver Bow Creek east of Rocker; Silver Bow Creek west of Rocker; Silver Bow Creek near Nissler; Silver Bow Creek near Ramsay; Silver Bow Creek near Miles Crossing; and Browns Gulch Creek near mouth.

Table 2-3 lists sampling sites, sampling frequencies, and parameters to be sampled for locations in Area II. In addition, measurement and sampling of bedload may be conducted at sites on Silver Bow Creek in Area II in accordance with procedures outlined in Section 4.4.4.3.

Area III

Surface water sampling stations in Area III will include permanent streamflow gaging sites described in Task 2, in addition to the following sites: German Gulch near mouth; Silver Bow Creek near the Gregson bridge; Mill-Willow Bypass near head; Silver Bow Creek above upper pH shack; and Mill-Willow Bypass above Pond 2 discharge. Locations of these sites are shown on Figure 2-2. Table 2-4 summarizes sampling station information for sites located in Area III.

TABLE 2-3.-- AREA II - SURFACE WATER SAMPLING SITES, SAMPLING FREQUENCIES, AND SAMPLE PARAMETERS

SITE NO.[a]	SITE LOCATION	SAMPLE ANALYTICAL CATEGORY[b,d],
SS-08	Silver Bow Creek east of Rocker	II
SS-09	Silver Bow Creek west of Rocker	II + CN (3)
SS-10	Silver Bow Creek near Nissler	III
SS-11	Silver Bow Creek near Ramsay	III + CN
SS-12	Browns Gulch at mouth	II
SS-13	Silver Bow Creek near Miles Crossing	III
SS-14	Gaging station near head of canyon	III + CN

Notes:

a) Sampling site locations shown on Figure 2-2.

b) Sample analyses parameter categories described in Table 2-2.

c) CN = cyanide. Sampling for this parameter will be discontinued it analytical results fail to note its presence.

d) Sampling frequency is as described in Table 2-1.

TABLE 2-4.-- AREA III - SURFACE WATER SAMPLING SITES, SAMPLING FREQUENCIES, AND SAMPLE PARAMETERS

SITE NO.[a]	SITE LOCATION	SAMPLE ANALYTICAL CATEGORY[b,c]
SS-15	German Gulch near mouth	II
SS-16	Silver Bow Creek near Gregson Bridge	II
SS-17	Gaging station near Highway 10A	II
SS-18	Mill-Willow By-Pass at head	II
SS-19	Silver Bow Creek above upper pH shack	II
SS-25	Mill-Willow By-Pass above Pond 2 discharge	II

Notes:

a) Sampling site locations shown on Figure 2-2.

b) Sample analyses parameter categories described in Table 2-2.

c) Sampling frequency is as described in Table 2-1.

Area IV

Area IV surface water sampling sites are shown in Figure 2-2. Table 2-5 summarizes sampling site information for Area IV. The areas recommended for sampling include: Pond No. 3; outlets from both decant towers of Pond No. 3; Pond No. 2; discharge from the Opportunity Ponds; and the Pond No. 1 pump-back system. Sampling parameters and frequency for Pond No. 2 discharge is contained in Section 2.1.2.3.

Area V

Area V surface water sampling sites are shown on Figure 2-2. These include the permanent gaging stations described in Task 2, in addition to several sites along the Clark Fork River below the Warm Springs Ponds.

Sampling stations SS-30 through SS-36 (Figure 2-2) are located on the Clark Fork River between the Warm Springs Ponds and Garrison Junction. These stations will be sampled twice during spring runoff; once each in May and June, 1985. Index parameters will be analyzed from samples collected at these stations to identify potential sources of metals contamination during spring high flow over this river reach. Sampling at the Clark Fork stations in May and June, 1985, will coincide with sampling conducted elsewhere such that accurate comparisons can be made between various reaches in

TABLE 2-5.-- AREA IV - SURFACE WATER SAMPLING SITES, SAMPLING FREQUENCIES, AND SAMPLE PARAMETERS

SITE NO.[a]	SITE LOCATION	SAMPLE ANALYTICAL CATEGORY[b,c]
SS-20	Pond Number 3	II
SS-21	East Decant Tower discharge	II
SS-22	West Decant Tower discharge	II
SS-23	South discharge ditch from Opportunity Ponds[d]	II
SS-24	North discharge ditch from Opportunity Ponds[d]	II
SS-26	Pond Number 2	II
SS-27	Pond Number 1 pumpback	II

Notes:

a) Sampling site locations shown on Figure 2-2.

b) Sample analyses parameter categories described in Table 2-2.

c) Sampling frequency is as described in Table 2-1.

d) Sampling for these sites will be coordinated with the Anaconda Smelter Remedial Investigation.

the hydrologic system. Table 2-6 summarizes surface water sampling site information in Area V.

2.1.1.4 Task 4 - Seepage Runs

Area I

A seepage run will be conducted on the Butte-Metro Storm Drain from gaging station SS-02 to gaging station SS-03, and on Silver Bow Creek from the Metro Storm Drain - Blacktail Creek confluence to the western edge of Area I. This seepage run will be conducted during fall base flow and will be coordinated with seepage runs conducted in other study areas.

Seepage run sites will include designated sampling sites described previously, in addition to several locales between these sites. Methodologies for measuring discharge and sampling procedures to be utilized during the seepage run are contained in Sections 4.4.4.5 and 4.4.4.2 respectively.

Area II

A seepage run will be conducted on Silver Bow Creek in Area II during fall base flow. Measurement and sampling sites will include sampling stations described previously, in addition to several other sites along the stream. Discharge measurement and sample

TABLE 2-6.-- AREA V - SURFACE WATER SAMPLING SITES, SAMPLING FREQUENCIES, AND SAMPLE PARAMETERS

SITE NO.[a]	SITE LOCATION	SAMPLE ANALYTICAL CATEGORY[b,c]
SS-28	USGS gaging station at Warm Springs Creek	II
SS-29	Clark Fork River below Warm Springs Ponds	II
SS-30	Clark Fork River near Racetrack	I + Cu, Fe
SS-31	Clark Fork River near Dempsey Creek confluence	I + Cu, Fe
SS-32	USGS gaging station on Clark Fork at Deer Lodge[d]	I + Cu, Fe
SS-33	Clark Fork River at R.R. Crossing 3 miles north of Deer Lodge[e]	I + Cu, Fe
SS-34	Clark Fork River near Mullan Gulch confluence	I + Cu, Fe
SS-35	Clark Fork River at R.R. Crossing 3 miles SE of Garrison Junction[e]	I + Cu, Fe
SS-36	Clark Fork River above confluence with Little Blackfoot River[e]	I + Cu, Fe

Notes:

a) Sampling site locations shown on Figure 2-2

b) Sample analyses parameter categories described in Table 2-2.

c) Sampling frequency is as described in Table 2-1 for stations SS-28 and SS-29. Other sites in Area V will be sampled twice; during spring high flows in May and June, 1985.

d) Sampling data for this site should be available from the WQB of MDHES.

e) These sampling sites are recommended to document off-site effects.

collection techiques will be utilized as described in Sections 4.4.4.5 and 4.4.4.2. All tributary input will be measured and included in the study. The seepage run will be conducted at the same time as those conducted in other study areas.

Area III

A seepage run will be conducted on the Mill-Willow Bypass during fall base flow. Measurement and sampling sites will include sampling stations described previously, in addition to several points between designated sampling sites. Discharge measurement and sample collection procedures will be as described in Sections 4.4.4.5 and 4.4.4.2. The seepage run will coincide with seepage runs conducted in other study areas.

2.1.1.5 Task 5 - Storm Runoff Sampling

The influences of storm runoff on Silver Bow Creek water quality may be quite different from those caused by spring snowmelt, and at least in the stream's upper reaches (Areas I and II), these influences may be due primarily to urban stormwater runoff (see Section 2.1.2). Accordingly, this task's objective is to determine the effects of stormwater runoff from tributaries in Areas I and II.

Efforts will be made to measure instantaneous discharges and collect water quality samples from the following tributaries during a storm

runoff event: Butte Metro Storm Drain (MSD) at head (SS-02); MSD at Kaw Avenue (SS-03); Blacktail Creek at mouth (SS-04); and Browns Gulch at mouth (SS-12). These sampling sites are shown on Figure 2-2. In addition, water quality and quantity will be measured at designated sampling stations on Silver Bow Creek below tributary input. Point source discharge sites will be sampled synchronously with the surface water sites during storm runoff, as described in Section 2.1.2.3.

2.1.2 Point Sources

Specific study tasks are described herein to determine the location, source, and severity of point source contamination to Silver Bow Creek and Clark Fork River. These tasks are to be conducted during Phase I, as described in Section 2.1. Certain tasks may be modified in Phase II, owing to analyses of data generated in Phase I.

2.1.2.1 Task 1 - Data Base Establishment

All available water quality and quantity data from known point sources will be sythesized and input to the data management system described in Section 2.1.1.1. These data will provide a historic data base with which data generated during this investigation will be compared and contrasted.

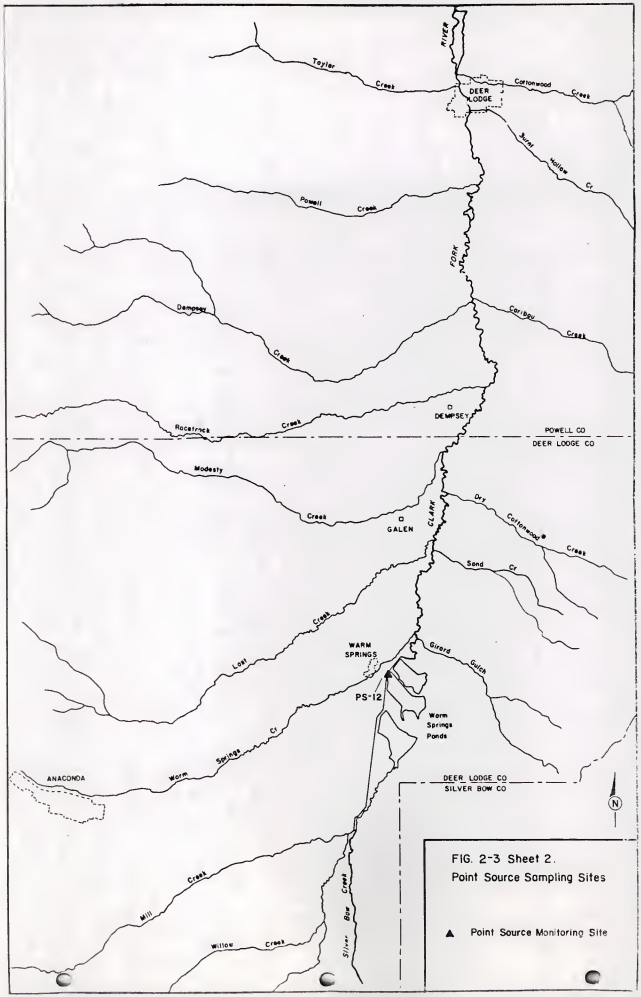
2.1.2.2 Task 2 - Reconnaissance Survey

A reconnaissance survey will be conducted along Silver Bow Creek from Butte to the Clark Fork River near Deer Lodge to confirm known point source discharges and identify suspected or undocumented point sources. During the survey, new point sources will be described as to location, type, areal extent, flow characteristics, and known or suspected source.

Significant point sources identified during the reconnaissance survey will be included in subsequent sampling and monitoring episodes, as described in the following tasks. Sampling frequency and parameters for newly identified point sources will be determined in consultation with appropriate MDHES personnel.

2.1.2.3 Task 3 - Point Source Sampling and Discharge Measurement

Routine water quality sampling and discharge measurements will be conducted at known point discharges in the study area. Grab samples will be obtained and discharge measurements will be made, when possible, at all point source sampling sites. Sampling and discharge measurement techniques are described in Section 4.4.4. Specific point source sampling sites are described below and are shown in Figure 2-3.


RIVER
Taylor
Creek
DEER LODGE
Cottonwood
Creek
Burns
Hollow
Cr
Powell
Creek
FORK
Dempsey
Creek
Caribou
Creek
DEMPSEY
Rocktrack
Creek
POWELL CO
DEER LODGE CO
Modesty
Creek
GALEN
CLARK
Dry
Cottonwood
Creek
Sand
Cr
Lost
Creek
WARM
SPRINGS
Gibbs
Gulch
PS-12
Worm
Springs
Ponds
Worm
Springs
Cr
ANACONDA
DEER LODGE CO
SILVER BOW CO
N
Mill
Creek
Willow
Creek
Silver
Bow
Creek
FIG. 2-3 Sheet 2.
Point Source Sampling Sites
▲ Point Source Monitoring Site

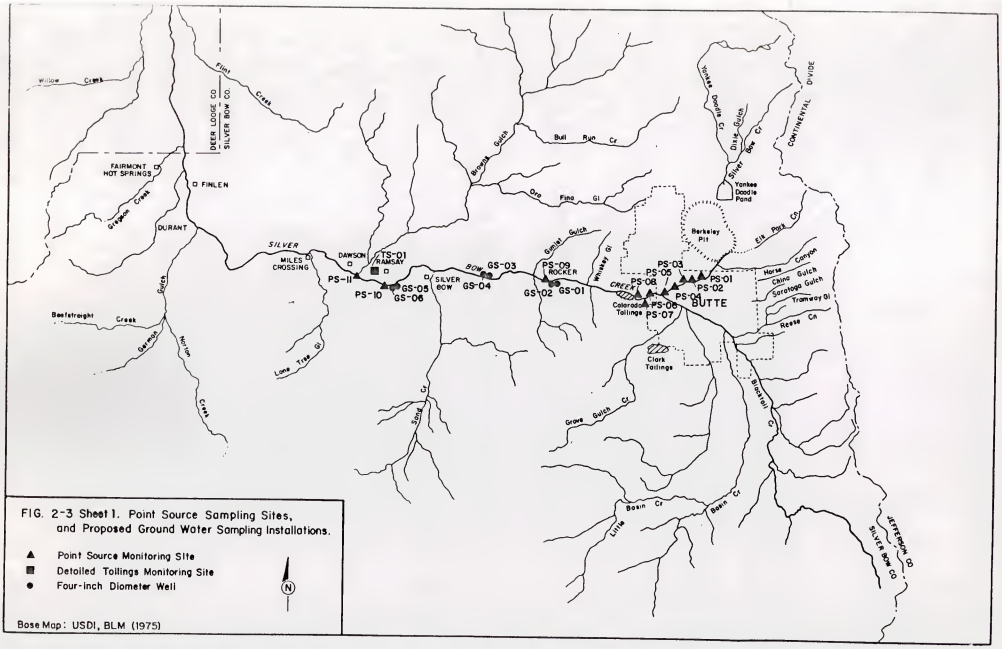


FIG. 2-3 Sheet 1. Point Source Sampling Sites, and Proposed Ground Water Sampling Installations.

- ▲ Point Source Monitoring Site
- ■ Detailed Tailings Monitoring Site
- ● Four-inch Diameter Well

Base Map: USDI, BLM (1975)

Task 3A - Butte-Metro Stormdrain Runoff Monitoring

Flow data will be obtained on a continuous basis for the Metro Storm Drain (MSD) at the Texas Avenue Bridge (gaging station SS-02) and at the Kaw Avenue Bridge (gaging station SS-03) as described in Section 2.1.1.2. Water sampling at these two stations will be in accordance with Section 2.1.1.3.

In addition to regular flow data collection at the MSD, sampling and flow measurements will be conducted at gaging stations SS-02 and SS-03 and on individual stormdrain outfalls to the MSD during two runoff events. These stormdrain outfalls are shown on Figure 2-3 and include: Warren Avenue (PS-01); Harrison Avenue (PS-02); Montana Street (PS-03); Missoula Gulch (PS-04); and Kaw Avenue (PS-05). One additional stormdrain outfall (PS-09), located near Rocker, will also be sampled during two storm runoff events. Parameters to be sampled at the stormdrain outfalls and sampling frequency are described in Table 2-7. The parameter list may be adjusted and additional sampling conducted during Phase II if warranted.

Every attempt will be made to obtain stormdrain runoff samples during the "first flush" when the greatest concentration of sediments are evacuated from the drain system. Pollutant concentrations in storm drain runoff can be highly variable with respect to time and location within the water column (U.S. EPA 1975). It is for this reason that flow composite samples will be obtained during all

TABLE 2-7 - POINT SOURCE SAMPLING ANALYTICAL AND FREQUENCY SCHEDULE

	SITE NO.[a]	SITE LOCATION	SAMPLING FREQUENCY	SAMPLE ANALYTICAL CATEGORY[b,c]
Stormdrain Outfalls	PS-01	Warren Avenue Storm Outfall	Fall, spring storm runoff	II
	PS-02	Harrison Avenue Storm Outfall	Fall, spring storm runoff	II
	PS-03	Montana Street Storm Outfall	Fall, spring storm runoff	II
	PS-04	Missoula Gulch Storm Outfall	Fall, spring storm runoff	II
	PS-05	Kaw Avenue Storm Outfall	Fall, spring storm runoff	II
	PS-09	Gimlet Gulch at Rocker	Fall, spring storm runoff	II
Domestic Point Source	PS-08	Butte STP discharge	Monthly[d]	II
Industrial Point Source	PS-06	Manganese Plant Seep	Quarterly	II
	PS-07	Seep near MP & T	Quarterly	I plus PCP, O & G
	PS-10	Seep near Stauffer Chemical	Quarterly	I plus PO4 and Total P
	PS-11	Silver Lake/ Georgetown Lake pipeline discharge	Monthly[d]	II
	PS-12	Pond No. 2 discharge	Monthly[d]	II

Notes:

a) Point Source locations shown on Figure 2.3.

b) Sample analyses parameter categories described in Table 2-2.

c) PCP-penthachlorophenol; O&G - oil and grease; PO_4 - ortho-phosphate; P - phosphorous (total).

d) Coincides with surface water sampling schedule (see Section 2.1.1.3).

sampling episodes. Sampling techniques are described in Section 4.4.4. Samples will be collected from the location within the runoff water column that will provide a representative sample of the parameter(s) of interest. When sampling for suspended solids or total metals, the sample will be taken near the bottom of the water column.

Task 3B - Domestic Point Sources

Composite water quality samples and discharge data will be collected at domestic point sources in the study area. The most significant domestic point source in the study area is discharge from the Butte Metro sewage treatment plant (PS-08, Figure 2-3). Table 2-7 presents the sampling frequency schedule and laboratory analyses parameters for this sample site. Other domestic point sources in the study area are less significant and impacts associated with these sites may be addressed, if warranted, in Phase II investigations.

Task 3C - Industrial Point Sources

Discharge measurements and water quality sampling will be conducted on a routine basis for all identified industrial point sources in the study area. These sites are shown on Figure 2-3 and include: Manganese plant seep (PS-06); seep near Montana Pole and Treating Plant (PS-07); seep near Stauffer Chemical Plant (PS-10); Silver

Lake/Georgetown Lake pipeline discharge (PS-11); and Warm Springs Pond 2 discharge (PS-12). Table 2-7 shows the sampling frequency schedules for these sites, as well as parameters to be analyzed.

2.1.3. Ground Water Work Plan

A work plan for Phase I of the hydrogeologic investigation of the Silver Bow Creek CERCLA site is described below to determine the general sources, extent, severity, and relationships with surface waters of ground water contamination in aquifers and tailings deposits adjacent to Silver Bow Creek and the upper Clark Fork River.

Objectives of the Phase I field investigation described in this work plan are to:

- Determine general ground water recharge/discharge conditions;
- Determine general rates and directions of shallow ground water movement;
- Quantify spatial and temporal hydrochemistry of shallow ground water to delineate between natural and contaminated waters;
- Quantify hydrologic relationships between shallow ground water and surface water systems;
- Confirm areal extent and depth of tailings and other wastes along Silver Bow Creek and the upper Clark Fork River;

- Quantify physical and chemical characteristics of tailings and related waste materials;
- Quantify unsaturated, vertical fluid movement through tailings and its effect on solute concentrations; and,
- Quantify temporal fluctuations of ground water levels within saturated tailings and the resultant effects of solute concentrations.

It is anticipated that additional ground water analyses will eventually be required for more specific information needs; however, because little is known about ground water contamination in the study area, detailed work plans for Phase II must await better definition of the problem resulting from Phase I activities. Phase I's duration will be four months, after which recommended activities for Phase II will be included in an interim report. Some tasks identified for Phase I will continue for the full twelve month Remedial Investigation. See also Section 2.5.1.1. Additional monitoring wells and piezometers, or detailed tailings water monitoring systems will be installed, if necessary, and added to the scheduled monitoring and data collection program in Phase II.

2.1.3.1 Task 1 - Data Base Establishment

All existing ground water quantity and quality data will be reviewed for accuracy and relevance and compiled into a master project file. The master project file will include a computerized data

management system capable of storing and recalling significant amounts of data, as well as extracting selected data for specific graphical, numerical, or statistical analyses.

Suspect data as established by screening with U.S. EPA criteria for data acceptance on "CERCLA" projects, will be used only as appropriate. Data collected by means other than the investigation's QA/QC plan will be used with caution for any purpose other than to provide background or planning information for the investigation team.

2.1.3.2 Task 2 - Existing Well Inventory

Existing domestic, livestock, irrigation, and monitoring wells within the Silver Bow Creek and upper Deer Lodge Valleys will be inventoried. Inventoried wells will be located within one mile of Silver Bow Creek or the Clark Fork River. This boundary is flexible, and will be left to the professional judgement of the investigators. This boundary is intended to narrow the area of interest, and thus limit the possible number of wells.

Sources of well inventory data include: Montana Department of Natural Resources and Conservation (DNRC) - Water Rights Bureau; Montana Bureau of Mines and Geology (MBMG); Montana Department of Health and Environmental Sciences; U.S. Geological Survey; U.S. Soil Conservation Service; Offices of Silver Bow, Deer Lodge, and

Powell Counties; Anaconda Minerals Company; Stauffer Chemical Company - Silver Bow Plant; and local water well drillers. Special attention will be paid to collecting and including data from the groundwater investigation on-going at the Opportunity Ponds as part of the Anaconda Smelter Remedial Investigation.

Data to be collected for the well inventory include: location; owner; well use; construction data; well construction characteristics, such as construction method, well depth, well diameter, casing material (e.g. concrete, steel, plastic, etc.), and type of pump; aquifer description; measuring point description and land surface elevations; availability of lithologic logs; and existing water quality data. A land survey of the locations and elevations of wells that have not been previously surveyed is specified in Task 2.1.3.5.

Area I - Summit Valley to Whiskey Gulch

Numerous wells are located in this area. Botz (1969) inventoried 82 wells in the Summit Valley, several of which are located in the northern portion of the valley. MBMG has installed wells and piezometers in the Colorado Tailings (Duaime and others 1982), and numerous wells along the Metro Storm Drain (Duaime 1984). These wells, in addition to other scattered wells installed by the MBMG and Anaconda Minerals Company, will be inventoried and appropriate well data collated.

Area II - Whiskey Gulch to Head of Canyon

No prior detailed studies have been conducted in this area. Monitoring wells have been installed at the Stauffer Chemical Company's Silver Bow plant. Many residences with wells are located along this portion of the valley; many are concentrated in the communities of Rocker, Silver Bow, and Ramsay. The inventory of these wells will begin with well logs on file with the DNRC Water Rights Bureau. Once the well logs are retrieved, wells will be located in the field and the reported information checked.

Area III - Head of Canyon to Warm Springs Ponds

Many domestic, stock, and irrigation wells are located in the southern portion of the Deer Lodge Valley. Konizeski and others (1961, 1962, 1968) inventoried 159 wells in the Deer Lodge Valley from the head of the Silver Bow Creek canyon to Deer Lodge. Many of these wells are located in Area III. Thirty-five wells were inventoried more recently in the area of Fairmont Hot Springs by MBMG (Sonderegger 1984). Many of these wells are the same as those inventoried by Konizeski and others (1961, 1962, 1968). These data will be compiled, and a review of DNRC files completed to identify newer wells.

Area IV - Warm Springs Ponds

No monitoring wells have apparently been installed specifically for the purpose of measuring the effects of seepage from the Warm Springs Ponds, (Hydrometrics 1983g). Anaconda Minerals Company has installed more than 40 observation wells in the vicinity of the Opportunity ponds, (Hydrometrics 1981b, 1983h). Information from these wells generated by the Anaconda Smelter Remedial Investigation may be useful for the investigation and will, if possible, be included in the inventory. Private stock, domestic, and irrigation wells located immediately north of the Warm Springs and Opportunity ponds will be inventoried. These data will be obtained from reports by Konizeski and others (1962, 1968), or from well logs on file with the DNCR Water Rights Bureau, or other appropriate sources. Data from any new wells installed as part of the Anaconda Smelter Remedial Investigation will be utilized as appropriate.

Area V - Clark Fork River

Most of the 159 wells inventoried by Konizeski and others (1961, 1962, 1968) are located along the Clark Fork River from the community of Warm Springs north to Deer Lodge. No significant ground water degradation is expected in this area; therefore, compilation of a well inventory need not be exhaustive. Those wells inventoried and deemed important will be field checked.

Area II - Whiskey Gulch to Head of Canyon

No prior detailed studies have been conducted in this area. Monitoring wells have been installed at the Stauffer Chemical Company's Silver Bow plant. Many residences with wells are located along this portion of the valley; many are concentrated in the communities of Rocker, Silver Bow, and Ramsay. The inventory of these wells will begin with well logs on file with the DNRC Water Rights Bureau. Once the well logs are retrieved, wells will be located in the field and the reported information checked.

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2.1.3.3 Task 3 - Tailings and Materials Sampling

Existing mapping of tailings (Hydrometrics, 1983e, g) will be confirmed. Maps exist which delineate the areal extent and thickness of tailings deposits along the Silver Bow Creek and Clark Fork River floodplains. Confirmation will involve two steps: 1) aerial photographic mapping of tailings; and, 2) spot field verification for ground control.

Sampling will be conducted at selected sites to determine the geochemical character of the tailings deposits. Sampling procedures, field equipment, and laboratory analyses will conform to those identified in the QA/QC Plan. Physical and chemical characteristics of the tailings or other waste materials to be determined in the field and laboratory are presented in Table 2-8. These data are necessary to accurately determine contaminant sources and pathways in the surface and ground water systems. As well, they are useful for assessing potential remedial measures. General sampling locations within the study area are presented below:

Area I-Summit Valley to Whiskey Gulch

Only four analyses of soluble metal levels have been completed of the Colorado Tailings (Hydrometrics 1983d). Additional soluble metal sampling is being performed by the MBMG on the Colorado Tailings during the drafting of this work plan. The results

TABLE 2-8.-- PARAMETER LIST FOR GEOCHEMICAL ANALYSES OF TAILINGS MATERIALS

FIELD DESCRIPTION OF PHYSICAL CHARACTERISTICS:

Texture	
Color	
Structure	
Consistence	
Mottling	
Stratification	
(other notable features)	

LABORATORY ANALYSES:

pH (1:1 water)	
Electrical conductivity	
Mechanical analyses	Hydrometer Method
Saturation percentage	
Calcium	Water Extractable Method
Magnesium	"
Sodium	"
Copper	"
Manganese	"
Iron	"
Zinc	"
Cadium	"
Lead	"
Sulfate	Ammonium Acetate (1N, pH 5.5) Extractable
Potassium	"
Total Sulfur	Method Described by Dacey & Colburn (1979)
Pyritic Sulfur	"
Arsenic	Hot Water Extractable Method
Molybdenum	"
Total Phosphorous	Bray Extraction Method
Nitrate	Phenyldisulfonic Acid Method

of this work will be reviewed. Depending on the applicability of this data to endangerment assessment and feasibility study-needs, additional sampling may be recommended. This would consist of an additional eith sample sites along an east-west transect. Sample sites will be roughly equally spaced to span deposit. Two-liter samples will be collected from three to four horizons within the tailings profile, with an additional sample collected from the original soil surface below the tailings, if possible. Depth of samples should correspond to lithologic or chemical changes.

Soil and earth materials samples will be taken and analyzed for PCP at the former Montana Pole and Treatment facility west of Montana Street and south of Silver Bow Creek. Ten sites will be selected at the facility based on field evidence of possible spills of diesel fuel oil containing PCP. Sample sites will be a grid or transect sampling network. Selection of the network will occur following a site visit by the Remedial Investigation Team. Each site will will be excavated or augerdrilled and samples taken for analysis from the following depth intervals: 0-12 inches, 12-36 inches, 36-72 inches, and greater than 72 inches. In all, a total of 40 samples will be collected.

Samples will likewise be obtained and analyzed for PCB from sediments and earth materials along the south bank of Silver Bow Creek in the vicinity of Montana Power Company's transformer storage facilities between Montana Street and Montana Pole and Treatment

plant. Six sites will be selected based upon field evidence of possible previous spills or leaks. Sample sites will be on a regular transect network. Transect locations will be determined by the Remedial Investigation Team following an initial site inspection. Each site will be excavated and samples collected for analysis from the following depth intervals: 0-12 inches and 12-36 inches. In all a total of 12 samples will be collected.

Area II - Whiskey Gulch to Head of Canyon

A number of samples have been collected and analysed from tailings along Silver Bow Creek in this study reach. There is an expectation that sediments along this reach account for a substantial amount of metal loading to Silver Bow Creek. Ten sample will be collected from evenly spaced sites along a transect paralleling the creek between Rocker and Ramsay. Four sites will be sampled along each of two normal transects to Silver Bow Creek at Rocker and Ramsay respectively. Three to four horizons, in addition to the original soil profile, will be sampled at each site.

Area III - Head of Canyon to Warm Springs Ponds

A few tailings samples have been collected along this reach of Silver Bow Creek. Mine wastes cover a one to three mile wide stretch of floodplain along this reach. Depths average six inches. Soil pH and metal content of these tailings deposits vary consider-

ably (Hydrometrics 1983e), resulting in a mosaic of vegetated and barren areas.

Additional samples and analyses are required along this reach to characterize the range of chemical conditions. Transects will be located at Gregson, Crackerville, and Opportunity. Samples will be collected from two transects oriented normal to the flow direction of Silver Bow Creek, and extending to the low terraces and coalescing fans bordering the valley. About ten sample sites will be required. Three samples per site will be collected from the tailings, and one sample will be collected from the original horizon of underlying soil. Lime content of soils with a pH above 8.0 (SCS 1971) will be determined in addition to the parameters listed in Table 2-8.

Area V - Clark Fork River

Transects will be sampled at Warm Springs, Dempsey, and Deer Lodge. A total of 26 sample sites will be required. One to two samples of tailings material and one sample of the underlying soil horizon will be collected at each site.

2.1.3.4 Task 4 - Phase I Well Installations and Tailings Vadose-Zone Monitoring Stations

Ground water monitoring wells will be installed during Phase I to document ground water conditions at locations identified to have

little or no detailed data. These wells will be installed, developed, and tested following methodologies presented in Section 4.4.5. Wells installed as part of this task will be monitored and sampled for the duration of the Remedial Investigation in accordance with schedules presented in Tasks 2.1.3.6 and 2.1.3.7.

Data deficiencies to be addressed during Phase I are present in Area II - Whiskey Gulch to Head of Canyon. Preliminary data needs are concentrated primarily in Area II because little information is available regarding the hydrologic significance of extensive floodplain tailings deposits and one industrial site.

Area II - Whiskey Gulch to Head of Canyon

Monitoring well installation during Phase I will be concentrated in Area II. Installations in Area II will include four tailings and alluvial ground water wells, a detailed tailings ground water monitoring site, and two near the Stauffer Chemical Plant. These are summarized in Table 2-9.

The two miscellaneous monitoring sites will each consist of two nested, shallow, 4-inch diameter wells, one to be completed in tailings and the other completed in alluvium (wells GS-01 to GS-04 on Figure 2-3). The wells will be located as close to Silver Bow Creek as possible, given site conditions. The wells will be installed with locking-housings sufficiently-sized to contain contin-

TABLE 2-9.--GROUND WATER LEVEL MONITORING AND WATER QUALITY SAMPLING SCHEDULES

Site No.[a]	Number of Wells	Water Level Monitoring Frequency[b]	Water Quality Sampling Frequency[b]	Parameter List[c]	Special Parameters Included
GS-01	(1)	Cont	M	P	
GS-02	(1)	Cont	M	P	
GS-03	(1)	Cont	M	P	
GS-04	(1)	Cont	M	P	
GS-05	(1)	M	Q	C	Total Phosphorous
GS-06	(1)	M	Q	C	Total Phosphorous
TS-01	(1)	Cont	M	P	
	(1)	Cont	M	P	
	(2)	M	-	-	
	(3)	M	-	-	
Lysimeters	(4)	-	M	P	
Selected Existing Private Wells	(75)	M	-	-	
Selected Existing Private Wells (approx 20-30)		-	Q	P	

Notes:

a) General site locations shown on Figure 2-3.

b) Q = Quarterly
M = Monthly (Sept through January) mid biweekly (February through July).
Cont = Continuous

c) All wells will initially be sampled for the complete parameter list.
All subsequent sampling will be for parameters to be determined from initial results.
C = Complete
P = Partial Parameter List (see Table 2-11)

uous water level recorders. The wells will be sited in close proximity to Silver Bow Creek surface water monitoring stations (Figure 2-2). Water level data monitored at these sites, for both saturated tailings and underlying alluvium, will be correlatable with stage and flow in Silver Bow Creek. The data will measure the direct relationships between the surface water and shallow ground water systems, and will document the effects of stream bank storage on metals concentrations.

The detailed monitoring site will be established to measure the effects on metals concentrations of infiltration through and ground water level fluctuations within floodplain tailings deposits. The site will be constructed at sufficient distance from Silver Bow Creek to avoid effects of stream bank storage. The site is tentatively located as shown on Figure 2-3 ; (TS-01) near the community of Ramsay.

The site will be installed to measure the chemistry of tailings solutions in relation to the water table to identify contamination causes from acid production from reduced zones. The site will consist of two nested 4-inch diameter wells, one installed in the tailings and one in the alluvial aquifer, to measure respective water table elevations. These wells will be installed with locking-housings, sufficiently-sized to contain continuous water level recorders. Five 2-inch diameter wells, 2 completed in tailings and 3 completed in the alluvium, will also be installed. These will be installed for the primary purpose of observing water

levels during pump testing, and will be located at short distances (5 to 50 feet) in a radial pattern from the 4-inch diameter alluvial well. These wells will be installed with locking, steel security covers. Construction characteristics for wells at the site are summarized in Table 2-10.

Tensiometers, gypsum blocks, and suction lysimeters will be nested at four depths to measure water potential and to collect samples of the tailings solution in the vadose-zone periodically through the year. Depth of installations will depend on ground water saturation. These instruments will be installed and operated according to methods outlined in Section 4.4.5.5.

Two 4-inch diameter wells will be installed in alluvium just northwest of the evaporation pond at the Stauffer Chemical Company - Silver Bow Plant. Existing ground water monitoring wells at the plant are discussed in Section 3.1.3. General locations of the new wells to be installed are shown of Figure 2-3. The new wells will be located between the county road and Silver Bow Creek, in the vicinity of Well 6 (an existing Stauffer monitoring well). Specific locations will depend on the judgment of the investigators and conditions such as property access, as discussed in Section 4.4.5. General construction characteristics of the two wells are summarized in Table 2-10.

TABLE 2-10.--SUMMARY OF MONITORING WELL CONSTRUCTION CHARACTERISTICS

Site No.	No. of Wells	Casing Diameter (in)	Estimated Well Depth (ft)	Target Aquifer	Proposed Aquifer Testing Method[b,c]	Purpose
GS-01	(1)	4	30-40	SBC Alluvium	Pumping	Alluvium/tailin
GS-02	(1)	4	10-15	Tailings	Slug	"
GS-03	(1)	4	30-40	SBC Alluvium	Pumping	"
GS-04	(1)	4	10-15	Tailings	Slug	"
GS-05	(1)	4	50-75	SBC Alluvium	Pumping	Stauffer Chemi
GS-06	(1)	4	50-75	"	Slug	"
TS-01	(1)	4	30-40	"	Pumping	Vadose-Zone Moni
	(1)	4	10-15	Tailings	Observation	"
	(2)	2	10-15	Tailings	Observation	"
	(3)	2	30-40	SBC Alluvium	Observation	"

Notes:

a) General site locations shown on Figure 2-3.

b) Testing Methods discussed in Section 4.4.5.3.

c) Wells will be installed and developed as described in Sections 4.4.5.1 and 4.4.5.2.

2.1.3.5 Task 5 - Land Survey

A survey to measure well locations and elevations will be conducted following completion of the well inventory and well installation tasks (Task 2 and Task 4) and prior to initiation of ground water level monitoring (Task 6). Only wells selected for inclusion in the ground water level monitoring program will be surveyed. Also, only those existing wells that have not previously been surveyed will be surveyed.

The survey will be conducted to determine locations to the nearest foot relative to a section corner for the purpose of accurately plotting locations on the study base map. At locations where well clusters have been installed, only one of the wells needs to be surveyed for location. The others can be measured relative to the surveyed well.

Elevations will be determined to the nearest 0.1 feet relative to mean sea level (MSL). Established U.S. Geological Survey bench marks will serve as datum points. The a priori established measuring points on all wells will be surveyed. Ground surface elevations at these sites will be measured by tape from the surveyed point.

2.1.3.6 Task 6 - Ground Water Level Monitoring Program

Approximately 75 private wells throughout the Silver Bow Creek

study area in addition to the installed well will be selected for periodic or continuous water level monitoring for the entire twelve month investigation period. The proposed monitoring schedules are summarized in Table 2-9. Selection of the private wells to be monitored will be completed following an evaluation of existing well data and compilation of the detailed well inventory. Selection of wells to be monitored for water levels will be based on several criteria. These are:

- Well location and source aquifer relative to conceptual hydrologic model;
- Well location relative to geographic areas and known or suspected problem areas;
- Accessibility to well site; and,
- Accessibility to property.

Two types of monitoring will be conducted: periodic and continuous.

Periodic Monitoring

Water levels in most wells, particulary private wells, will be monitored on a periodic schedule. Monthly measurements of static water levels will be conducted following procedures outlined in Section 4.4.5. Each well will be scheduled to be measured on about the same day each month. All wells, if possible, will be measured during the same week. Measurement periods will be concurrent with surface water monitoring.

The four tensiometers and gypsum blocks of the tailings vadose-zone monitoring station will be monitored on a monthly schedule, except for the months of May and June when measurements will be made biweekly.

Continuous Monitoring

Six 4-inch diameter wells installed in Task 4 will be equipped with continuous water level recording devices (Table 2-9). These devices will be installed, operated, and maintained as described in Section 4.4.5.

2.1.3.7 Task 7 - Ground Water Quality Sampling Program

Approximately 30 to 40 wells will be designated for a ground water quality sampling program. The wells designated for sampling will be a subset of the larger number included in the water level monitoring program. Water quality sampling schedules are listed in Table 2-9. The specific number and location of the private wells to be sampled will be determined following compilation of the list of wells to be monitored for monthly or continuous water level recording.

The water quality sampling program will be organized into two levels for both sampling frequency and sampling parameters. Sampling frequency will be divided into monthly and quarterly. A monthly

sampling frequency will be comprised of one sample per month for, at a minimum, the duration of Phase I. The sample frequency for Phase II will be determined after evaluation of the results of Phase I data.

A quarterly sampling frequency will be comprised of one sample every three months. This frequency may be modified to monthly should evidence of significant ground water degradation at a site be encountered. The quarterly frequency sampling is intended for wells where rapid changes in ground water chemistry are not anticipated.

Sampling parameters are divided into partial and complete, and are identified in Table 2-11. Initial samples from all wells will be analyzed for the complete parameter list to determine significant solute species.

Of the 30 to 40 wells to be included in the initial ground water quality sampling network, ten wells will be sampled monthly. Six of these ten wells will be the four-inch wells installed as part of Task 4 (Section 2.1.3.4). The remaining 20 to 30 wells will be sampled quarterly.

Lysimeters at the detailed tailings vadose-zone monitoring site will be sampled initially for a complete parameter list. Monthly sampling will then be conducted for the partial analysis parameter list. Sampling frequency and parameters may be modified following

TABLE 2-11.--PARAMETER LIST FOR GROUND WATER CHEMICAL ANALYSES

COMPLETE ANALYSIS

Field Measurement:
pH
Specific Conductance
Temperature

Lab Measurement:

Total Dissolved Solids
Calcium
Magnesium
Sodium
Potassium
Bicarbonate
Sulfate
Chloride
Fluoride
Arsenic[a]
Cadmium[a]
Copper[a]
Iron[a]
Lead[a]
Zinc[a]

PARTIAL ANALYSIS

Field Measurement:
pH
Specific Conductance
Temperature

Lab Measurement:

Total Dissolved Solids
Sulfate
Arsenic[a]
Cadmium[a]
Copper[a]
Iron[a]
Lead[a]
Zinc[a]

---

[a]Dissolved constituents.

Phase I data analysis. It is anticipated that sampling frequency from some wells may be increased during Phase II to account for ground water flux associated with spring snowmelt.

2.2 BIOLOGICAL INVESTIGATIONS

2.2.1 Aquatic Communities

2.2.1.1 Area I; Summit Valley to Whiskey Gulch

Fisheries

No fisheries studies are recommended for this area.

Macroinvertebrates

A "paper study" which consolidates all available invertebrate data on Silver Bow Creek and the Upper Clark Fork River will be preformed. This study will draw upon existing studies (Chadwick and Associates 1983; Harner White Ecological Consultants 1982) and unpublished studies describing the past and existing conditions of the macroinvertebrate communities. No field work will be performed. The report prepared as a result of this effort shall present all available data in summary and detail.

Algae

The objective of the algal study is to make as assessment regarding the role algae play in removing or transporting metals within the Silver Bow Creek, Warm Springs Ponds, and Upper Clark Fork River

system. This investigation is designed as an assessment, not as a full fledged study into mechanisms or efficiencies. The proposed sampling program is shown in Table 2-12. However, based on the initial sampling episode, the second episode may be reduced or expanded. Based on first episode findings, algae determinant factors (e.g. nutrients) may also be recommended for measurement.

Data generated by this investigation will be used to determine if the algae compartment of the system concentrates metals above the ambient levels. This determination will be made measuring metal content of the algae compartment and comparing it to the ambient values generated by the surfacewater investigation.

Artificial substrate (plexiglass) samples will be analyzed for chlorophyll a and will estimate the amount of algal production taking place. Chlorophyll a will be corrected for pheophytin pigment interference. These samples will also be analyzed for metal content. The exposure period for the substrate will be be determined by examining past algal studies on Silver Bow Creek, and as appropriate, the same exposure periods will be used.

Whole water samples collected with a Van Dorn bottle will be used to measure chlorophyll, algal species, and metals absorbed by algae. Two samples will be collected from each Pond. Laboratory methods for determination of chlorophyll, algal biomass, and algal metal absorption are described in Appendix 4.4.6.

TABLE 2-12.--ALGAL INVESTIGATIONS SAMPLING SCHEDULE

Location	Artificial	Whole Water	Water Chemistry
Blacktail Creek above confluence with Silver Bow Creek	S	S	AS/SW
Below Colorado Tailings and STP	S	S	AS/SW
Miles Crossing below Browns Gulch	S	S	AS/SW
Pond 3	S	S	AS/SW
Pond 2	S	S	AS/SW
Clark Fork River Deer Lodge	S	S	AS/SW

S = Seasonal (March, August)

Artificial--chlorophyll and metal absorption

Whole Water--Chlorophyll, metal absorption, algal species identification and enumeration, and diversity

AS/SW = As per surface water program described in Section 2.1.

2.2.1.2 Area II; Whiskey Gulch to Head of Canyon

Fisheries

No fisheries studies are recommended for this area.

Macroinvertebrates

See Section 2.2.1.1 for recommended program.

Algae

See Section 2.2.1.1 for recommended program.

2.2.1.3 Area III; Head of Canyon to Warm Springs Ponds

Fisheries

No fisheries studies are recommended for this area.

Macroinvertebrates

See Section 2.2.1.1 for recommended program.

Algae

See Section 2.2.1.1 for recommended program.

2.2.1.4 Area IV; Warm Springs Ponds

Fisheries

A study to determine levels of Silver Bow Creek contaminants in tissues of fish residing in the Warm Springs Ponds will be implemented. A study of this type must address the following in order to meet the objectives outlined in Section 3.2:

- Dates of sampling;
- Locations of sampling;
- Species to be sampled;
- Number of individuals of each species;
- Age of individuals sampled;
- Collection methods;
- Tissues to be analyzed;
- Tissue preparation methods;
- Laboratory analytical methods;
- Parameters to be measured; and
- Data summaries and statistics.

Table 2-13 summarizes the recommended program of study for the fish

TABLE 2-13.--WARM SPRINGS PONDS FISH TISSUES INVESTIGATION

Dates of Sampling	Once as Convenient
Location of Sampling	Pond 2
Species Sampled	Trout, Brown or Rainbow
Number of Individuals of each Species at each Period at each Place	25*
Age of Individuals of each Species	Trout - Age Class III if possible
Collection Method	Appendix 4.4.7
Tissues for Analysis	Edible portion: a fillet including skin
Tissue Preparation Method	Appendix 4.4.9
Laboratory Analysis Method	Appendix 4.4.10
Parameters to be Measured	As, Cd, Pb, Hg
Data Summary and Statistics	Appendix 4.4.11

* Determined by statistical analysis of available data to calculate number of samples required to reach a pre-determined level of confidence in the means generated.

investigation at the Warm Springs Ponds and how the program responds to each of these criteria.

2.2.1.5 Area V; Clark Fork River

Fisheries

Two fishery studies are recommended; these are a chronic flow-through bioassay study and a viable gamete study. The chronic flow-through study location will be determined in consultation with MDFWP. The proposed viable gamete study will utilize wild brown trout gametes collected from the Clark Fork River and will be performed at a locations selected by MDFWP. The performance of the viable gamete study will depend on the results of the chronic flow-through study.

Sampling time will correspond with the availability of hatchery embryos and larval fish for the chronic flow-through part of the study. The sampling time for the viable gamete study will be coordinated with the peak spawning period of wild brown trout in the Upper Clark Fork River.

Flow-Through Study

Test Organisms: including gametes, embryos, and fish will be obtained from a hatchery that has been certified disease-free. Obtaining

gametes and embroys from a facility that supports survival, growth, and reproduction of aquatic organisms also eliminates the need for doing tissue analysis on the brood stock.

The investigator will obtain and report all pertinent data regarding brood stock for gametes or embryos obtained from outside facilities. This information will include the strain or geographic race of the brood stock, number of males and females used, their age, recent temperature, and feeding and disease history.

Three females and three males will be used in obtaining gametes. Unfertilized eggs and semen can be transported for a period of 24 hours after stripping, provided they are kept in plastic bags free of air. Semen and unfertilized eggs will be chilled on ice during shipment. The investigator will avoid exposing either the eggs or semen to water before fertilization. Previous tests with coho salmon and steelhead trout have indicated fertility exceeds 90 percent when at least 250 µl of semen is used per 50 ml of eggs.

Testing equipment, calibration, flow rates, cleaning, dilution water, test concentrations, fertilization of gametes, test procedures, test duration, data collection, and feeding are described in detail in 4.4.2.19.

Viable Gamete Study

If the chronic flow through study shows significant affects to fish from Clark Fork River water, then a viable gamete study is recommended as a follow up to determine if the water significantly affects gamete viability and therefore reproductive success.

Gametes will be collected from wild brown trout populations in the field and from brown trout hatchery brood stock by experienced personnel. Pertinent data needed for adult fish used as brood stock and procedures for transporting gametes can be found in Section 4.4.19.

Fertilization of gametes, testing procedures for embryos, and data collection will be the same as their respective flow-through sections. The only major differences that exist are in the equipment selected for incubation chambers and the test sites.

Each test site will consist of duplicate collections of fertilized gametes, wild brown trout gametes and hatchery brood stock. Five sites are recommended for testing. Three sites are recommended for testing on the Clark Fork River, one just below the Warm Springs Ponds, one below Deer Lodge, and one at Garrison above the confluence with the Little Blackfoot River. Two tributaries sites are recommended for sampling just above their confluence with the Clark Fork River; The Little Blackfoot River and Cottonwood Creek.

Data analysis will involve ANOVA to determine if fertilization (%) and hatching success (%) are affected by gamete source or location. The precision and accuracy of the test will be assured by following the appropriate methodology and pertinent items listed in the Accuracy And Precision In Toxicology Testing section in Section 4.4.21.

Macroinvertebrates

The recommended program for this area is described in subsection 2.2.1.1.

Algae

The recommended program for this area is described in subsection 2.2.1.1.

2.2.2 Natural Terrestrial Communities

2.2.2.1 Area I; Summit Valley to Whiskey Gulch

Floral Communities

As presented in Section 3.2.2 of this report, it is recommended that the flood plain vegetation of Silver Bow Creek to Whiskey Gulch be mapped at the largest available scale and that each mapping unit's vegetation be described qualitatively. To accomplish this task

the following activities will be completed.

- Acquire recent aerial photography of the flood plain area from appropriate sources at the largest available scale. Potential sources include: USEPA-Helena, Montana (1:7,000 from Butte to Warm Springs and other low-level aerial photography of the Summit Valley, Jim Dunn 1984); USGS National Cartographic Information Center, Denver, Colorado (1:24,000 orthophotoquads); and MultiTech file photos from past projects in the Summit Valley (various scales).

- Establish preliminary mapping units by reviewing the acquired photography and identifying similar photo-signatures, then going to the field for a reconnaissance effort to verify the identified units. As appropriate, riparian vegetation will be classified into mapping units using the following references: 1) A Taxonomic Classification System for Montana Riparian Vegetation (Montana State Rural Areas Development Committee 1982); 2) Riparian Ecosystems: Their Ecology and Status (USFWS 1981); and 3) Classification of Wetlands and Deep Water Habitats of the United States (USFWS 1979).

- Map the selected preliminary units at the largest available scale for the area of interest.

- Field verify each mapping unit by examining it in the field; make changes to mapping units as necessary.

- Prepare a final vegetation map of the selected area at a common scale. If a common scale is not available, then changing scales by use of a pantograph will only be done by scaling up, not down. If scaling up is not available, then the maps will be finalized at different scales.

- Measure areal extent of each mapping unit using an accurate planimeter.

- Data presented will be a combination of mapped data and tabular data. Mapped data will show the location and aeral extent of each mapping unit. Tabular data will show the species occurrence within each mapping unit and the total areal coverage of each unit.

Completion of these activities will enable an investigator to examine the data and utilize it in the manner discussed in Section 3.2.2 of this report.

2.2.2.2 Area II; Whiskey Gulch to Head of Canyon

Floral Communities

The methodology outlined for Area I will be applied to this area.

Faunal Communities

No wildlife studies are recommended for this area.

2.2.2.3 Area III; Head of Canyon to Warm Springs Ponds

Floral Communities

The methodology outlined for Area I will be applied to this area.

Faunal Communities

No wildlife studies are recommended for this area.

2.2.2.4 Area IV; Warm Springs Ponds

Floral Communities

The methodology outlined for Area I will be applied to this area.

Faunal Communities

One wildlife-related study is recommended for the Warm Springs Ponds Area. This study is an evaluation of waterfowl tissue contamination from Silver Bow Creek.

Meeting the objectives of this study as described in Section 3.2.2 requires the following issues be addressed for each group of organisms recommended for sampling:

- Dates of sampling;
- Locations of sampling;
- Species to be sampled;
- Number of individuals of each species;
- Age of organism sampled;
- Collection methods;
- Tissues to be analyzed;
- Tissue preparation methods;
- Laboratory analytical methods;
- Parameters to be measured; and
- Data summaries and statistics.

Table 2-14 summarizes the recommended program of study for the Waterfowl Investigation at Warm Springs Ponds and how the program responds to each of these criteria.

One critera this table does not address is the selection of sites for sample collection within each of the areas described in line two of Table 2-14. For waterfowl, the presence of a bird on or above a specific area will make that bird eligible for inclusion as a sample from that area. Water sample sites are discussed in Section 2.1. Sediment sample sites will be sampled as outlined in Section 2.1.

TABLE 2-14.--WARM SPRINGS PONDS WATERFOWL INVESTIGATION[a]

	WATERFOWL	FISH	WATER	SEDIMENT
Dates of sampling	Jan, Sept, Nov	AS/FS	AS/SW	AS/SM
Locations of sampling	Warm Springs Ponds	AS/FS	AS/SW	AS/SM
Species to be sampled	Mallard	AS/FS	N.A.	N.A.
Number of individuals of each age of each species at each period at each place	25[b]	AS/FS	N.A.	N.A.
Age of individuals of each species	Adult, except in Sept., then Juvenile	AS/FS	N.A.	N.A.
Collection methods	Appendix 4.4.8	AS/FS	AS/SW	AS/SM
Tissues for analyses	Breast	AS/FS	N.A.	N.A.
Tissue preparation method	Appendix 4.4.9	AS/FS	N.A.	N.A.
Lab. analytical methods	Appendix 4.4.10	AS/FS	AS/SW	AS/SM
Parameters to be measured	As, Cd, Cu, Pb, Hg, Zn	As, Cd, Cu, Pb, Hg, Zn	AS/SW	AS/SM
Data summaries and statistics	Appendix 4.4.11	AS/FS	AS/SW	AS/SM

AS/SW = As per surface water sampling program.
AS/SM = As per sediment sampling program.
AS/FS = As per fish sampling program.

Notes:

[a] = Macroinvertebrate, macrophyte, and microphyte sampling may be recommended to determine potential pathways of contamination following waterfowl testing.

[b] = Determined by statistical analysis of available data by calculating number of samples required to reach a predetermined level of confidence in the means generated.

The sampling program identified in Table 2-14 is only a recommended program. Following the first sampling episode that data will be analyzed. Depending on the results found, the next sampling episode may be reduced or expanded.

2.2.2.5 Area V; Clark Fork River

No wildlife studies are recommended for this area.

2.2.3 Agricultural Systems

2.2.3.1 Methodological Overview

These investigations will be implemented using a two phased approach. The first phase will be a reconnaissance study to evaluate the approximate areal extent and severity of "heavy metal" contamination effects on irrigated croplands and livestock; to a lesser degree, subsequent human health effects will be surmised. To the extent that significant affects to agricultural production or human health appear evident, a second phase will then occur. A brief summary of each phase's objectives is presented in the following text.

The first task of Phase I will utilize existing (i.e. SCS, MBMG, etc) and reconnaissance-level ("new") data, wherein no levels of statistical confidence and sampling precision have been established beforehand. The numerically reduced data will be analyzed stat-

istically, with the results then compared against the appropriate sample matrix/sample use (e.g., soil/phytotoxicity) assessment criteria. These evaluations will be used to determine the need for further sampling and analysis.

The second task of Phase I will involve reconnaissance level sampling at additional sites, and may involve laboratory analyses for additional parameters (e.g., sodium adsorption ratio). As such sampling will be guided by levels of confidence and precision determinted beforehand, the statistical validity of the overall data base will be enhanced. The statistically analyzed results will allow refined characterization of "heavy metal" accumulation affects throughout the terrestrial food chain. Phase II would be determined by the findings of Phase I studies, with additional sampling and analysis possible.

Crops and Soils

The simplified trace element cycling-terrestrial food chain model used to design the remedial investigation work plans is shown in Figure 3-2. The initial step was the identification of those (potentially biotoxic) contaminants generated by mineral processing activities. This effort included estimation of pollutants released into water and air (environmental) pathways. Previous water quality investigations (Section 3.1 of the draft Work Plan) present data on trace element burdens in surface and ground waters. The identifi-

cation and demarcation of irrigated crops and soils potentially affected by use of such contaminated waters are discussed briefly in Section 3.2.3. The demarcation of irrigated lands affected currently and/or historically via the air pathway (e.g., fugitive dust, aerial deposition of "flue dust") is discussed elsewhere, (e.g., MultiTech 1984a).

In regards to soils and crops, two objectives are proposed. The primary objective is the identification, demarcation, and pertinent investigation of those irrigated lands affected currently and/or historically by use of "heavy metal" contaminated water(s). The secondary objective is the separation of respective contributions from the water and air pathways to the observed or suspected contamination problems. This lesser objective will compliment the "far-field" aspect(s) of the Anaconda Smelter study, (CH_2M Hill 1984), and will aid in evaluation of remedial technological fixes for problem areas. The proposed investigation flow sheet for the soil-crop studies is shown in Figure 2-4.

Livestock

The purpose of the livestock-related Phase I work plan is the identification, demarcation, and pertinent investigation of those cattle, horse, and sheep populations that have, or may have, been affected by consumption of contaminated water and/or feed (including ingested soil) sources. A secondary objective will be the evalua-

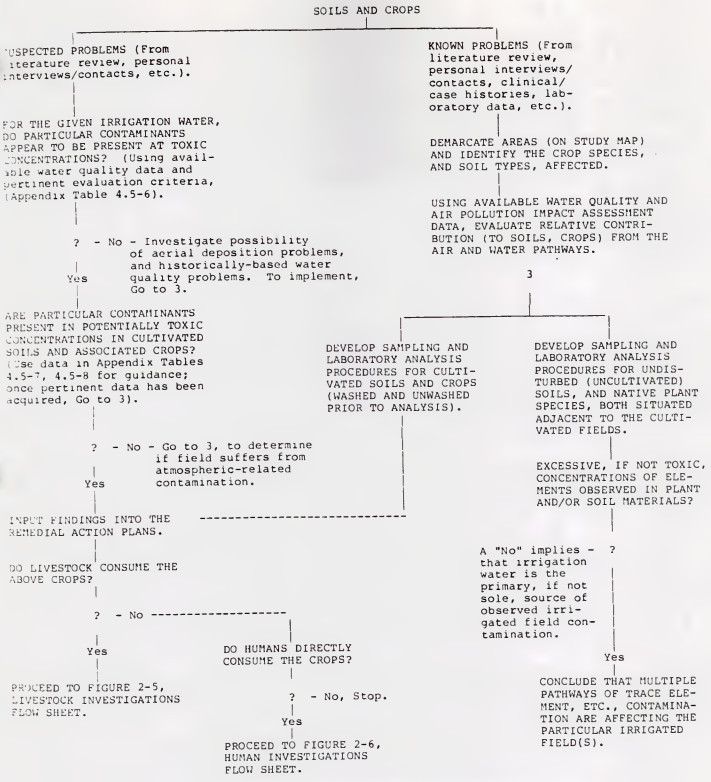

SOILS AND CROPS
SUSPECTED PROBLEMS (From literature review, personal interviews/contacts, etc.).
KNOWN PROBLEMS (From literature review, personal interviews/ contacts, clinical/ case histories, laboratory data, etc.).
FOR THE GIVEN IRRIGATION WATER, DO PARTICULAR CONTAMINANTS APPEAR TO BE PRESENT AT TOXIC CONCENTRATIONS? (Using available water quality data and pertinent evaluation criteria, (Appendix Table 4.5-6).
DEMARCATE AREAS (ON STUDY MAP) AND IDENTIFY THE CROP SPECIES, AND SOIL TYPES, AFFECTED.
USING AVAILABLE WATER QUALITY AND AIR POLLUTION IMPACT ASSESSMENT DATA, EVALUATE RELATIVE CONTRIBUTION (TO SOILS, CROPS) FROM THE AIR AND WATER PATHWAYS.
? - No - Investigate possibility of aerial deposition problems, and historically-based water quality problems. To implement, Go to 3.
Yes
3
ARE PARTICULAR CONTAMINANTS PRESENT IN POTENTIALLY TOXIC CONCENTRATIONS IN CULTIVATED SOILS AND ASSOCIATED CROPS? (Use data in Appendix Tables 4.5-7, 4.5-8 for guidance; once pertinent data has been acquired, Go to 3).
DEVELOP SAMPLING AND LABORATORY ANALYSIS PROCEDURES FOR CULTIVATED SOILS AND CROPS (WASHED AND UNWASHED PRIOR TO ANALYSIS).
DEVELOP SAMPLING AND LABORATORY ANALYSIS PROCEDURES FOR UNDISTURBED (UNCULTIVATED) SOILS, AND NATIVE PLANT SPECIES, BOTH SITUATED ADJACENT TO THE CULTIVATED FIELDS.
? - No - Go to 3, to determine if field suffers from atmospheric-related contamination.
Yes
EXCESSIVE, IF NOT TOXIC, CONCENTRATIONS OF ELEMENTS OBSERVED IN PLANT AND/OR SOIL MATERIALS?
INPUT FINDINGS INTO THE REMEDIAL ACTION PLANS.
A "No" implies - that irrigation water is the primary, if not sole, source of observed irrigated field contamination.
?
DO LIVESTOCK CONSUME THE ABOVE CROPS?
? - No
Yes
Yes
DO HUMANS DIRECTLY CONSUME THE CROPS?
CONCLUDE THAT MULTIPLE PATHWAYS OF TRACE ELEMENT, ETC., CONTAMINATION ARE AFFECTING THE PARTICULAR IRRIGATED FIELD(S).
PROCEED TO FIGURE 2-5, LIVESTOCK INVESTIGATIONS FLOW SHEET.
? - No, Stop.
Yes
PROCEED TO FIGURE 2-6, HUMAN INVESTIGATIONS FLOW SHEET.

FIGURE 2-4.--INVESTIGATION FLOW-SHEET FOR THE SOIL-CROP STUDIES

tion of animal tissues (e.g., liver) and animal products (e.g., milk) for possible transfer of unsafe trace element levels to the human consumer. The proposed investigation scheme is shown in Figure 2-5. As shown in Figure 2-5, livestock sampling during the Phase I reconnaisance will only occur if specific criteria are met.

Humans

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, 94 Stat. 2779) provides a mechanism for identifying and treating those non-controlled hazardous waste sites otherwise unregulated by Federal statute, etc. The prime intent is protection of human health and safety, with lesser emphasis being placed on threats to welfare and economics. The proposed work plans (regarding agricultural production) address economic-welfare concerns, but anticipate also possible adverse affects on human health and safety. The means of integrating the proposed studies with these concern is shown in Figure 2-6. Such evaluations will be discussed in the report that documents the results of the implemented work plans.

2.2.3.2 Determination of the Soils-Crops and Livestock Sampling Patterns

Study Area Boundary, Sampling Locations, and Sampling Intensities

The literature review completed, and personal contacts established,

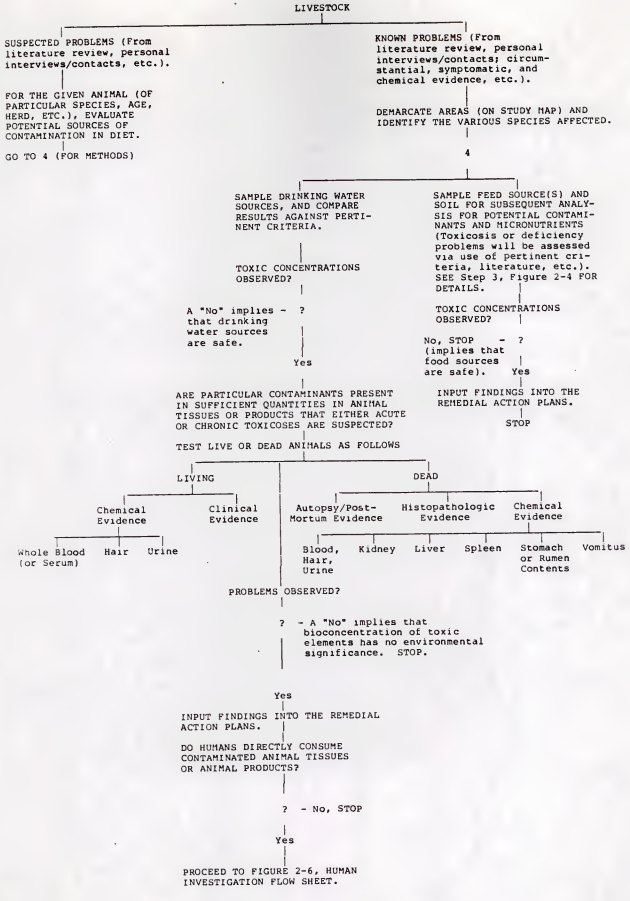

LIVESTOCK
SUSPECTED PROBLEMS (From literature review, personal interviews/contacts, etc.).
FOR THE GIVEN ANIMAL (OF PARTICULAR SPECIES, AGE, HERD, ETC.), EVALUATE POTENTIAL SOURCES OF CONTAMINATION IN DIET.
GO TO 4 (FOR METHODS)
KNOWN PROBLEMS (From literature review, personal interviews/contacts; circumstantial, symptomatic, and chemical evidence, etc.).
DEMARCATE AREAS (ON STUDY MAP) AND IDENTIFY THE VARIOUS SPECIES AFFECTED.
4
SAMPLE DRINKING WATER SOURCES, AND COMPARE RESULTS AGAINST PERTINENT CRITERIA.
TOXIC CONCENTRATIONS OBSERVED?
A "No" implies - ? that drinking water sources are safe.
Yes
SAMPLE FEED SOURCE(S) AND SOIL FOR SUBSEQUENT ANALYSIS FOR POTENTIAL CONTAMINANTS AND MICRONUTRIENTS (Toxicosis or deficiency problems will be assessed via use of pertinent criteria, literature, etc.). SEE Step 3, Figure 2-4 FOR DETAILS.
TOXIC CONCENTRATIONS OBSERVED?
No, STOP - ? (implies that food sources are safe).
Yes
INPUT FINDINGS INTO THE REMEDIAL ACTION PLANS.
STOP
ARE PARTICULAR CONTAMINANTS PRESENT IN SUFFICIENT QUANTITIES IN ANIMAL TISSUES OR PRODUCTS THAT EITHER ACUTE OR CHRONIC TOXICOSES ARE SUSPECTED?
TEST LIVE OR DEAD ANIMALS AS FOLLOWS
LIVING
DEAD
Chemical Evidence
Clinical Evidence
Autopsy/Post-Mortum Evidence
Histopathologic Evidence
Chemical Evidence
Whole Blood (or Serum)
Hair
Urine
Blood, Hair, Urine
Kidney
Liver
Spleen
Stomach or Rumen Contents
Vomitus
PROBLEMS OBSERVED?
? - A "No" implies that bioconcentration of toxic elements has no environmental significance. STOP.
Yes
INPUT FINDINGS INTO THE REMEDIAL ACTION PLANS.
DO HUMANS DIRECTLY CONSUME CONTAMINATED ANIMAL TISSUES OR ANIMAL PRODUCTS?
? - No, STOP
Yes
PROCEED TO FIGURE 2-6, HUMAN INVESTIGATION FLOW SHEET.

FIGURE 2-5.--INVESTIGATION FLOW SHEET FOR THE LIVESTOCK STUDIES

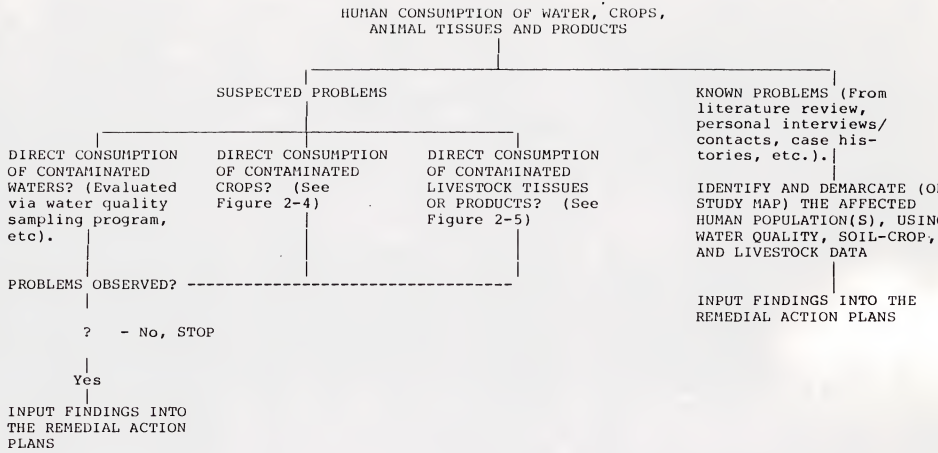

HUMAN CONSUMPTION OF WATER, CROPS, ANIMAL TISSUES AND PRODUCTS
SUSPECTED PROBLEMS
KNOWN PROBLEMS (From literature review, personal interviews/ contacts, case histories, etc.).
DIRECT CONSUMPTION OF CONTAMINATED WATERS? (Evaluated via water quality sampling program, etc).
DIRECT CONSUMPTION OF CONTAMINATED CROPS? (See Figure 2-4)
DIRECT CONSUMPTION OF CONTAMINATED LIVESTOCK TISSUES OR PRODUCTS? (See Figure 2-5)
PROBLEMS OBSERVED?
? - No, STOP
Yes
INPUT FINDINGS INTO THE REMEDIAL ACTION PLANS
IDENTIFY AND DEMARCATE (ON STUDY MAP) THE AFFECTED HUMAN POPULATION(S), USING WATER QUALITY, SOIL-CROP, AND LIVESTOCK DATA
INPUT FINDINGS INTO THE REMEDIAL ACTION PLANS

FIGURE 2-6.--TENTATIVE FLOW-SHEET FOR (PRELIMINARY) HUMAN HEALTH AND SAFETY INVESTIGATIONS

to date reveal insufficient information to rigorously demarcate the total-affected study area. However, it appears as though approximately 5,380 acres of irrigated land may be affected within Deer Lodge and Powell Counties. This estimate was made via mensuration of those lands receiving water either pumped or diverted from the Silver Bow Creek/Upper Clark Fork River. The derivation of this figure is presented in Table 2-15, (Buck et al. 1955a,b; 1959).

At study onset, the known and potentially affected landowners will be identified and demarcated on the appropriate study area map. This effort will be accomplished by contacting at least those individuals listed in Appendix Table 4.5-5, by phone. The general line of questioning is summarized in Figure 2-7. For those individuals judged willing to participate in the study (i.e., allow field sampling, etc.), personal interviews will be scheduled at the land owner's convenience. At these interviews, site-specific details for each agricultural operation will be acquired. Ideally, such information will include the data given in Figure 2-8. At the conclusion of these on-site visits, the Phase I study area boundaries will be demarcated on the master sampling map (Exhibit 1), and on other maps as required.

The "comments" included in Appendix Table 4.5-5 indicate that at least 12 (different) landowners have, or may have, problems with "heavy metal" contaminated irrigation waters and/or contaminated croplands. Furthermore, it is reasonable to assume that 6 to 12

TABLE 2-15.--DERIVATION OF THE ESTIMATE FOR POTENTIALLY AFFECTED, IRRIGATED, LANDS PRESENT WITHIN THE STUDY AREA

Location (Township N Range W)	Acres Affected	Comments
T4NR10W, Sections 21, 28, 35	~ 180	May be affected by seepage from the Yellow Ditch, which diverts water from Silver Bow Creek (T3NR10W, Section 1bbc).
T5NR9W, Sections 29, 30	~ 50	Appears to be irrigated from the Whitcraft Ditch, which may receive some seepage from the Opportunity Ponds (T5NR10W, Section 36cc).
T5NR9W, Section 5	~ 120	Appears to be irrigated from the Helen Johnson and Johnson Ditches.
T5NR10W, Sections 13, 23, 24	~ 580	Possibly affected by seepage or subirrigation (by effluents) from the Opportunity Ponds.
T6NR9W, Sections 20, 21, 29, 32	~ 185	Appears to receive Clark Fork River water from A. Beck, Helen Johnson or Johnson-Hoffman Ditches, or from the West Side Canal.
T6NR9W, Sections 5, 8, 9, 16, 17	~ 465	Apparently receives irrigation waters from the Johnson-Eliason or Eliason Ditches, or from the West Side Canal.
T7NR9W, Sections 4, 5, 8, 9, 17, 20, 29, 32	~ 980	Appears to receive waters from the Valitor East Side and West Side Ditches, the Eliason Lateral Ditch, and the West Side Ditch (Canal).
T8NR9W, Sections 3, 10, 15, 16, 21, 28, 29, 32	~ 1400	Appears to receive waters from the West Side Ditch, Warren Pump/Kohrs-Manning Ditch, Stuart Ditch, Mollenberg-Nelson-Pauly Ditch, and Lahman Ditch.

TABLE 2-15.--DERIVATION OF THE ESTIMATE FOR POTENTIALLY AFFECTED, IRRIGATED, LANDS PRESENT WITHIN THE STUDY AREA (Continued)

Location (Township N Range W)	Acres Affected	Comments
T9NR9W, Sections, 29, 30, 32, 33, 34	~ 380	Appears to receive waters from the Kohrs-Manning Ditch, Larson Ditch, Mollenberg-Nelson-Pauly Ditch, and Lahman Ditch.
T9NR10W, Sections 8, 11, 14, 24	~ 140	Appears to receive waters from the Lahman Ditches, Knop Ditch, and Gilman pump-sprinkler system.
T10NR10W, Section 31	~ 20	Appears to receive water from Dutton pump and ditch system.
T10NR11W, Sections 19-23, 26, 29, 30	~ 880	Appears to receive waters from the Dutton Wallace, Wallace-Bissonette-Blum and Dunkleburg-Meadows-Turnbull Ditches.
	Σ ~ 5,380	

Sources: Buck et al. 1955 a, b; 1959.

INTRODUCTION/BACKGROUND MATERIAL:

1. Name, occupation, name-address of employer (stated by caller);a

2. Currently investigating whether or not crops-forage irrigated with, or livestock consuming, Silver Bow Creek or Upper Clark Fork River water(s) have been affected by past effluents from the smelter operations;

3. Once such known or potential areas are identified-demarcated, would like to gather soil, crop, water, and/or livestock samples for later analysis in the laboratory. The results would be evaluated to check the possibility of contaminated fields, etc; and

4. Have visited with Deer Lodge SCS personnel and they think (contact's) land (and/or livestock) may be affected, or (contact) may be interested in participating in the study, so decided to call.

5. Could I ask you a few simple questions? (If no, ask if a personal visit could be arranged. If still no, thank them for their time and delete their name from the sample-site list). If they respond favorably to the first request, proceed as given below.

QUESTIONS:

1. Do you irrigate using water from either the Clark Fork River or from Silver Bow Creek? (If no, go to question No. 5).

2. How do you usually irrigate (i.e., pumping, subirrigation, diversion) and what sort of crops do you usually grow? (list).

3. Have the lands been irrigated for a long time? (Number of years if known).

4. When does the irrigation season usually begin and end? (Dates).

5. Do you have any ground that doesn't have plants growing in it, or cultivated fields that you have problems with, or "funny colored" soils? (If no, go to question No. 6) If yes, try to acquire general location(s) and description of conditions, especially guesses as to the acreage(s) involved.

FIGURE 2-7.--PHONE INTERVIEW PROTOCOLS

QUESTIONS (Continued):

6. Have you ever had your soils or crops tested? For what? Can we see the results? (If yes, the individual is a good prospect).

7. Do you own any cattle, sheep, or horses? (If no, go to question No. 11).

8. Do your animals drink from Silver Bow Creek or Clark Fork River? (If no, go on to question No. 9).
If yes, do you think any problems have occurred from doing so? (If no, go to question No. 9). Otherwise, describe particular situations where such problems are known or suspected.

9. Do your animals eat crops or forage grown using Silver Bow Creek or Clark Fork River water? (If no, go to question No. 10). Otherwise, what crop types?

10. Have you ever submitted animal parts or animal products for chemical analysis? For what? Can we see the results? (If yes, the individual is definitely a good prospect).

11. Could someone visit with you, at your convenience, at some particular date and time? (If no, thank them for their time and place their name on the "suspect" list, for possible sampling in the future).

12. If yes (to No. 11), acquire sufficient information to find their residence, and arrange a meeting time. Thank them for their time and cooperation.

Note:

a) See potential candidate list, Appendix Table 4.5-5, for initiation of phone interview efforts.

FIGURE 2-7.--PHONE INTERVIEW PROTOCOLS (Continued)

INTRODUCTION

1. State name, occupation, and name-address of employer; leave business card. Make sure the landowner's name, address, and occupation have been recorded correctly.

INFORMATION TO BE ACQUIRED, IF POSSIBLE OR PERMISSIBLE

1. Acres owned and/or leased?

2. Irrigated acreage, by crop type, or total acres irrigated? Dryland acreage?

3. Existence of a home garden, types and quantities of crops grown?

4. Observations on the number of cow/calf, feeder cattle and dairy cattle units, plus apparent numbers of horses, swine, sheep, and poultry present.

5. Existence of wells for livestock watering or potable water; note number, locations, and inquire whether any water quality analyses and/or well-completion data (e.g., pump tests, driller's logs, etc.) are available. If so, can they be inspected?

6. Inspect those fields and/or livestock where contamination problems are known or are suspected. Following landowner permission, photodocument sites and gather preliminary data (including grab samples) as judged necessary.

7. If laboratory data (i.e., for soils, crops, livestock, water) are available, request informally access to the information. If the owner agrees, record the data as follows:

Sample No.	Date Acquired	Date Analyzed	Service Performed (Data)	Lab Name/ Address

Other pertinent comments_____.

8. If additional information is available (via landowner permission), but which requires his/her written permission to access, the following permission form will be used. The master sheet will be mailed to the appropriate agency office(s), while the carbon copy is mailed to the Contractor for inclusion in project files.

FIGURE 2-8.--LANDOWNER PERSONAL CONTACT PROTOCOLS

PERMISSION FORM
To Review Livestock Autopsy and Laboratory Analysis Results

I, (Landowner's Name) consent to allow representatives of the Contractor to obtain a copy of analytical tests performed by the Veterinarian Diagnostic Laboratory or Chemistry Station Analytical Services. I understand that the information will be reviewed for the purposes of implementing the work plan for the investigation of Silver Bow Creek and the Upper Clark Fork River.

I have had the following tests performed:

Sample Number	Date	Service Performed (Autopsy, Tissue Analysis, Etc.)
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Other pertinent comments: _____

_____

_____

_____

_____

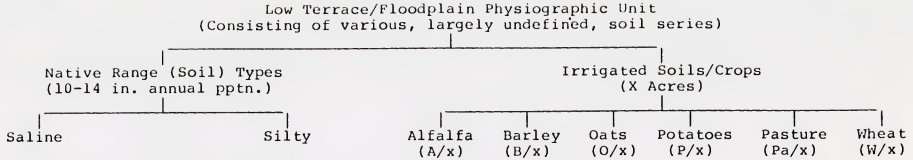
_____ _____

Signature Date

FIGURE 2-8.--LANDOWNER PERSONAL CONTACT PROTOCOLS (Continued)

additional landowners will be identified during the phone-field level field-sampling group. Following numerical reduction of the laboratory data, sampling precision and confidence level will be evaluated.

The Phase II effort will utilize a stratified-proportional approach if the reconnaissance level data indicates it is necessary for an endangerment assessment. In regards to Phase II sampling intensity, it is recommended that sample precision (P_x) and confidence level (C.L.) be set at 0.20 and 90 percent, respectively, for the key parameters selected. Ideally, most--if not all-- of the Phase II sample requirements will have been acquired during the first phase efforts. The utilization of these values represents a perceived "balance" between economic constraints and the acquisition of scientifically defensible data. These values will ensure production of analytical data for each sampled stratum that is within 20 percent of the population mean, at 90 percent confidence. The stepwise procedure for acquiring the necessary sample size (per stratum) is shown in Figure 2-9. Presently, insufficient information exists to make a Phase II sample size estimate that satisfies the above statistical expectations. However, a credible range varies from 12 to 200 additional sites. The lower range presumes the following: 1) 24 participating landowners in total, each possessing only one type of crop; and 2) sufficient homogeneity within the particular crop (between landowners) that the initial sample taken per field collectively satisfies the above statistical requirements.



Procedures:

1. Select (more-or-less randomly) one of the Phase I sample site location within each crop type (field) sampled. Ideally, at least one representative from each crop type cultivated will be available. Let the total sample number = n.

2. For each crop species, soil depth interval and trace element (e.g., Arsenic in alfalfa, and in associated 4-12 in. soil interval), transform the laboratory data using base 10 logarithms so as to "normalize" the data.

3. Calculate total sample number, N, needed to satisfy the apriori levels of sampling precision (p) and confidence level. The sample number is determined as follows:

$$N = \left(\frac{ts}{px} \right)^2$$

where t = Student's two-tailed "t"-statistic for (n-1) degrees of freedom; s = arithmetic sample standard deviation of the log-transformed data; p = precision of the mean; and $\bar{x}$ = arithmetic sample mean of the log-transformed data.

4. Once N is calculated for all matrix (soil or crop) - trace element combinations, the largest of these values, N, is designated as representing the total sample size needed to satisfy the given statistical requirements. Thus, the number of additional (Phase II) samples needed is determined by subtracting n from N, equalling N'.

FIGURE 2-9.--PROTOCOLS FOR DETERMINING PHASE II SAMPLE SIZE AND LOCATIONS

Procedures (Continued):

5. The proportioning of N' among the various crop types is calculated as follows: for alfalfa, (A acres/x, total acres) x N'; for barley, (B/x)N', etc. For example, if 2500 total acres are judged to be affected, of which 820 acres are alfalfa, while 55 additional samples must be taken, then (820/2500) x 55 or 18 additional samples will be allocated to alfalfa fields throughout the study area.

6. Once the sample numbers are determined by crop species, they are in turn proportioned by respective size of the field. For example, if alfalfa fields A, B, C, and D occupy 0.3, 0.4, 0.2, and 0.1 of the 820 acres (total), then sample allocation will be as follows: for field A, (246/820)(18) = 5 sites; for field B, (328/820)(18) = 7 sites, etc.

7. Native range (soils) will be sampled adjacent to those fields, per crop species, that require the greatest number of additional samples. For example, alfalfa field B would be selected, as 7 of the 18 (total) samples will be taken there. The contribution of stack-originating trace element burden to the "lesser" cultivated fields (e.g., alfalfa fields A, C, and D) will be evaluated via extrapolation of the native soil data from the "major" crop site to the particular "lesser" crop site(s). This step will be aided by use of the "far-field" data provided by Phase 1 of the smelter-related studies, (CH_2M Hill 1984).

FIGURE 2-9.--PROTOCOLS FOR DETERMINING PHASE II SAMPLE SIZE AND LOCATIONS (Continued)

The upper range presumes the following: 1) 50 participating landowners each possessing two crop types; and 2) sufficient heterogeneity within each particular crop that a second sample must be taken (per field) in order to satisfy the above statistical requirements. Furthermore, limited sampling of uncultivated soils-native range sites lying adjacent to the "major" irrigated cropland sites during Phase II is suggested. Such data would allow assessment of the combined effects of aerial deposition and irrigation water. In particular, this scheme should be considered for those cropland sites situated outside of the "farfield" area designated by CH_2M Hill (1984; Figure 13). Thus, 3 "uncultivated", additional, sites are recommended, based on a review of the pertinent literature, (Buck et al. 1955b, 1959; MultiTech 1984a).

Phase II Cropland Sampling Site Selection Criteria

Upon completion of the listing of probable sampling locations, the list will be finalized using three essential criteria (per crop type). These criteria are as follows: 1) probable ease in gaining site access; 2) the apparent completeness of site-specific crop production and soil tillage/fertilization records; and 3) distribution of a particular irrigated crop type (e.g., haylands) at varying distances downstream from the smelter facility.

Livestock Sampling Pattern

The phone contact and personal interview efforts (Figures 2-7, 2-8) will provide preliminary information on the location and herd size of livestock known to be, or potentially, affected by consumption of contaminated feed and/or water supplies. The final listing of animal populations to be sampled will be determined from a follow-up visit (to each particular livestock owner) by a qualified veterinarian. This person will utilize the available autopsy and tissue analyses data, plus site-specific confirmation of classic "heavy metal" toxicosis syndromes observed, to compile the master list of sampling sites. These sites will be demarcated on the master sampling map (Exhibit 1), or other maps as required.

At present, the sampling precision and statistical confidence (resulting from the above efforts) cannot be quantified. However, Dollhopf et al. (1984) have argued that 10 herds of cattle, each containing at least 25 head, must be sampled (within 5 miles of the East Helena Smelter works) in order to provide 95% confidence that the data base will be ±20% of the true mean (per trace element). These sampling criteria were judged to be sufficiently accurate to identify those herds which have been affected adversely by smelter (stack) emissions. Therefore, in the absence of a rigorous statistical basis for livestock sampling, the following criteria will be used. First, all herds or bands sampled will be located on the home ranch on a year-round basis, and preferably are associated

with cultivation of irrigated crops. Secondly, sampling of at of at least two (and preferably 10) populations per livestock species should be attempted, where each population is composed of at least three (and preferably $\geq$ 25) animals.

The Phase II livestock sampling efforts will focus upon those stiuations wherein a high probability of "heavy metal" poisoning exists, as judged by the project veterinarian. For budgetary purposes, initial sample size per species is as follows: cattle, 30 head; sheep, 5 head, and; horses, 2 head. These reconnaissance level estimates are probably 10 percent of sample numbers required to meet a sampling precision of ~0.2 and statistical confidence of ~85 percent. The derivation of such numbers for a statistically enhanced Phase 2 investigation--if warranted by endangerment assessment requirements--are presented in Table 2-16. An alternative approach is to: 1) specify statistical constraints beforehand, 2) log-normalize the Phase 1 data (per species-element contamination), and then 3) proceed in a manner similar to that presented for soils-croplands (Figure 2-9).

In regards to cattle, Dr. Maurice Hull (Dollhopf et al. 1984) estimated that 420 animals must be sampled in order to meet the stated objectives of the East Helena smelter study. This sum is based upon the following: 220 head located within five miles of the smelter works; 125 head present at distances greater than five miles (radius) of the smelter; and 75 animals located at unspecified control sites.

TABLE 2-16.--RATIONALE FOR DERIVATION OF PHASE II LIVESTOCK SAMPLING SIZES

PART A. DATA UTILIZED AND ASSUMPTIONS MADE[a]

1. The mean annual occupation by irrigated haylands is 58,610 acres (for the period 1972-1981) in Deer Lodge and Powell Counties. Assume this value is representative of long-term (future) conditions.

2. The mean annual inventory of dairy-beef cattle, sheep-lambs, and horses is 33,236; 4,822; and 1,700 head, in Deer Lodge and Powell Counties. Assume these values are representative of long-term conditions.

3. Table 2-15 shows that ~5,380 acres of irrigated land are potentially affected within Deer Lodge and Powell Counties. Assume this number is correct, and that all such lands are for hay production.

4. From the above data, the estimated proportion of irrigated lands affected adversely, via use of "heavy-metal" contaminated water is (5,380 ÷ 58,610) =0.09179. Assume that this ratio applies also to livestock affected by consumption of contaminated feed and/or water.

5. Assume that 10 percent of the affected population, per livestock species, must be subject to hair and whole blood sampling in order to meet the apriori statistical requirements.

PART B. DERIVATION OF SAMPLE SIZES

1. Cattle: 33,236 total population x 0.09179 affected population x 0.10 sampling requirements = 305 head.

2. Sheep: 4,822 x 0.09179 x 0.10 = 44 head.

3. Horses: 1,700 x 0.09179 x 0.10 = 16 head.

Note: a) The derivation of irrigated hayland and livestock inventory figures utilized agricultural statistics compiled by the Montana Department of Agriculture, for the period 1972-1981.

Determination of "Site Avoidance" Criteria

It is probable that a number of environmental conditions or factors exist within the study area that, if sampled, would yield results that would only confound attempts to evaluate contaminated irrigation water effects on exposed agricultural materials (i.e., soils, crops, livestock). Thus, those areas exibiting any of the following characteristics will not be sampled. These conditions include: 1) sites located within 100 feet of a linear transport (emission source), i.e, railroads, vehicle roadways/parking lots; 2) sites located within 150-feet of a point or area emission source, i.e., vehicle repair/fueling areas, welding/plumbing/machine shops, and any fossil-fueled combustion system regulated by Federal or Montana State environmental agencies; 3) sites located within 20 feet of any surface or area which may have received an application of metal-bearing chemicals, solvents, paint, etc; 4) "native range" sites under or immediately adjacent to shrubs or other structures that may have affected the aerodynamic patterns of trace metal deposition in their vicinities; and 5) severely eroded sites (of varying steepness), as such areas probably contain abnormally low metal concentrations. In addition, care will be taken to avoid those areas which are 1) practically inaccessible, i.e., permanently flooded areas, cliffs, impenetrable ground, and areas wherein trespass rights cannot be obtained; and 2) areas known or suspected to be highly mineralized (i.e., "natural geochemical anomalies"). Thus, no sampling within 200-feet of a working or abandoned surface

or underground mine site, or within the vicinities of prospect holes/trenches/pits, etc., will occur. Finally, any other area known or suspected to have been disturbed by such processes as land-leveling or created by land-filling activities will not be sampled. Tilled soils will be sampled only at designated irrigated cropland (sampling) sites.

2.2.3.3 Soil Sampling

Site Description/Documentation Procedures

Each site will be located in accordance with the reconnaissance or stratification methodologies discussed in subsection 2.2.3.2, including the environmental constraint criteria. In those cases where environmental constraints force the actually sampled site to deviate in some vector fashion away from the "office-mapped" site, the distance/ direction relationship(s) between the respective locations will be determined and recorded in the manner discussed below. The "random" sites will not possess any of the constraints discussed in subsection 2.2.3.2.

The rationale(s) used to demarcate the actual sample site will be recorded on both the sampling site description form (Appendix, Table 4.5-13) and in the field diary.

In addition to those field document control responsibilities dis-

cussed above, it is recommended that a field sample record book and a field diary be maintained. The sample record book will include at least the following: 1) date, personnel present, and weather/field sampling conditions; 2) a legal description of each sample site's location, including mention of any necessary site relocation (due to various environmental constraints); 3) the sequential numbers given to each (respective sample) matrix acquired per given plot; and 4) verification of sample transfers from the field crew to the sample bank at the conclusion of each working day. As each crew leader will possess the master copy of the particular weather proof field book, it is recommended that each day's records be photocopied upon completion of the chain-of-custody procedure. Thus, a "back-up" copy of all records will be kept at the sample bank and will be available in the event of loss of the master copy.

The field diary will include all other matters of importance which are not marked on the topographic map(s) and/or aerial photography, or in the sample record book. The diary will include at least the following information: 1) date, personnel present, weather/field sampling conditions and sites visited; 2) any technical or logistical problems encountered and solutions attempted; and 3) any comments useful towards improving the present or future sampling programs of the present nature. This daily record will be maintained at the sample bank. The diary will be completed on a daily basis and be filed in project offices for use by the crew leader(s) and by the project leader (for preparation of progress reports, etc.). These

records will be reviewed by the project manager at least weekly to assure adherence to the above plan.

Sample Acquisition and Sample Analysis methods are described in Appendices 4.4.12 and 4.4.13, respectively.

The Sample Bank will be responsible for generating homogeneous soil samples. The drying, grinding, and sieving processes are discussed in Appendix 4.4.13. At the time of analysis, the Sample Bank issues a subsample of the appropriately prepared sample to the particular laboratory personnel in need of it. The unused (unanalyzed) materials shall be returned to the Sample Bank.

Those soil samples identified as being trace element (triplicate) splits on the sample collection tag will be dried and mixed, and then split into three separate samples for analysis. One of the split samples will be shipped to the referee analytical laboratory. The identification of these split samples must be documented in the master log. Crop and livestock samples identified as being duplicates on the sample collection tag will also be shipped to the same analytical laboratory.

The equipment used for drying, sieving, and mixing the soil must be decontaminated after each sample processed and at the end of each day. Between samples, all equipment will be blown clean with compressed air to remove contamination (e.g., materials caught in the

screen, along edges of collection pans, etc.). Following this procedure, each potentially contaminated component of the drying, sieving, mixing, and grinding equipment will be vacuumed and then wiped down using a sponge moistened with hot Alconox (0.01 percent w/v) solution. The equipment will then be rinsed with D.I. water, and wiped dry with a disposable Kimwipe® towel. The metal-free laboratory detergent and laboratory brushes or Kimwipes will be used also in the decontamination procedure at the end of each sample preparation day.

2.2.3.4 Soil Analytical Methods

Sample site numbers, number of samples acquired per site and analytical treatment schemes for soils are summarized in Part A of Table 2-17. Laboratory analytical methods for soils are described in Appendix 4.4.13.

2.2.3.5 Crop and Native Range Sampling Protocols

Site Description/Documentation Procedures

As in the case for uncultivated soils, the irrigated soils/cropland sites to be sampled on a particular day will be identified via inspection of the master sampling map (e.g., Exhibit 1), plus pertinent orthophoto- and topographic quadrangle sheets. This will be accomplished by the crew leader(s) prior to departure for the

TABLE 2-17.--SUMMARY OF RECOMMENDED ANALYTICAL REQUIREMENTS FOR SOILS AND VEGETATION

PART A. SOILS

Phase No.[a]	Sample Site Nos.[b]	No. Samples Per Site[c]	Analytical Treatment Scheme
I	12 "affected" sites and 4 "control" sites.	3 (i.e., 0-4, 4-12 and 12-28 inch depth intervals).	Re: "affected samples"-- • Determine initially pH, "plant-available" concs. of As, Cd, Cu, Pb, and Zn; electrical conductivity; ammonium, nitrate and phosphate ions. • If "heavy metal" contamination is significant, then analyze for organic carbon content; sulfate ion and pyritic sulfur; total lime requirement (if pH <6); "plant available concs. of Group 2 elements (see Table 4-6). • If salinity problems are suspected, then analyze for SAR (i.e., Ca, Mg, Na) and/or ESP; Saturation extract and saturation percentage determinations. Re: "control samples"-- • Determine all of above, plus remaining parameters presented in Appendix Table 4-6, including <u>total</u> metal analyses.
II	~12" affected" sites, ~3 "control sites, and ~3 "native range" (and/or garden) sites.	Ditto.	Re: "affected samples"--use treatment scheme presented above. Re: "control samples" and "native range" (and/or garden) samples--use treatment scheme presented above.

TABLE 2-17.--SUMMARY OF RECOMMENDED ANALYTICAL REQUIREMENTS FOR SOILS AND VEGETATION (CONTINUED)

PART B. CROPS/NATIVE RANGE SPECIES

Phase No.[a]	Sample Site Nos.[b]	No. Samples Per Site[c]	Analytical Treatment Scheme
I	12 "affected" sites and 4 "control" sites.	Assume 3:1 small grain:potatoes sampling ratio. One tuber (vegetative) sample per potato site and two samples (i.e., separate seedhead, vegetative tissue) per small grain site.	Re: "affected samples"-- • Determine initially As, Cd, Cu, Pb, and Zn (total concs.) • If "heavy metal" contamination appears significant, then analyze for total nitrogen and total phosphorus concs. Re: "control samples"-- • Determine concs. of all above parameters.
	~12 "affected" sites, ~3 "control" sites and ~3 "native range" (and/or garden) sites.	Assume 3:1:1 alfalfa: native pasture: winter wheat sampling ratio. Two samples per small grain site and one (vegetative or composite) sample per alfalfa, native pasture and "native range" site. If gardens are sampled, sample those tissues/parts that are consumed by humans.	Re: "affected samples"-- • Determine initially As, Cd, Cu, Pb, and Zn (total concs.); then total N and P, if warranted (see above). • If budget allows, run Group No. 2 metals (see Table 4-6) on those samples wherein "heavy metal" contamination is evident. Re: "control samples" and "native range" samples-- analyze for Group No. 1 and 2 metals, plus total N and total P.

TABLE 2-17.--SUMMARY OF RECOMMENDED ANALYTICAL REQUIREMENTS FOR SOILS AND VEGETATION (CONTINUED)

Notes: a) Phase I is tentatively scheduled for the period September 3, 1984 through December 28, 1984. Phase II is tentatively scheduled for the period June 17, 1985 through September 27, 1985.

b) The four Phase I control sites include one each of barley, spring wheat, oats and potatoes. The three Phase II control sites include one each of alfalfa, native pasture, and winter wheat; the three "native range" sites will be associated with the three largest "affected" fields (regardless of crop type) that are identified during the course of the study. If desired, garden plot(s) can be substituted for one or all of the rangeland sites.

c) Does not include field blanks, duplicates, etc.

field. In addition, any concerns regarding landowner contact/site access, appropriate schedule of sampling (e.g., to be compatible with the landowner's harvest schedules) will be resolved jointly by the crew boss and project leader before initiating the day's field work.

Initially, the location of each cropfield will be verified by the crew leader. He or she will then acquire landowner permission to create a semi-permanent reference point from which distance and direction to the actual sampling location can be related. The form shown in the Appendix 4.4.14 will be filled out for each site sampled.

Sample Acquisition Protocols

Upon arrival at a particular irrigated field, the crew leader will verify its geographical location and sample site number via inspection of the master sampling map (e.g., Exhibit 1). Initially, the point-of-departure into the particular field and observed site conditions will be documented, as discussed previously for soils sampling (subsection 2.2.3.3). When judged necessary, the field crew leader will contact and interview the owner (of a particular field) so as to solicit additional information on existing crop conditions (e.g., insect infestations, plant development problems) and types-amounts of fertilizers applied, since time of the "original" interview. The center of the 0.1-acre plot should be sit-

uated at least 100-feet away from any potential source of metallic particulate emissions (e.g., roadways, railroad lines, residences/ work areas). If a particular field contains more than one "heavy metal" affected crop species, they will be sampled at separate (0.1-acre) plots. Total plot numbers per species and field will be determined using the methodologies discussed in subsection 2.2.3.2.

The four ~one square-foot (ft^2) subplots will be laid out as shown in (Appendix) Figure 4.5. The crop species present within the subplots will be scored for percentage of yellowing (chlorosis) and dead areas (necrosis) present on the leaves, fruiting bodies, etc. The different types of visible injury symptoms may be recorded on color slide or print film, based upon the discretion of the field crew leader.

As macronutrient, micronutrient, and protein content vary seasonally for many non-cultivated grass species (e.g., Munshower and DePuit 1976), it is reasonable to expect similar occurrences in taxonomically similar cultivated species. However, in order to reduce project costs, the sampling of each crop type will occur at the most optimum time for protein production. These specific sampling periods will therefore occur throughout the growing season. The general timing is as follows: first cutting for hay and orchard grass pastures (prior to seed head initiation); alfalfa when at prebloom (but apical buds present); while small grain species immediately preceeding harvest (i.e., at physiological maturity).

The exact time for sampling a particular crop will be determined via consultation with the local county extension agent, SCS personnel, and/or the producers of these crops. Appendix 4.4.14 describes the crop sample acquisition protocols in more detail.

2.2.3.6 Laboratory Analytical Methods for Crop and Native Plant Species

Sample site numbers, number of samples acquired per site, and analytical treatment schemes for plant materials are summarized in Part B of Table 2-17. Laboratory analytical methods for crops and native plants are described in Appendix 4.4.15.

2.2.3.7 Field Sampling of Livestock Tissues

Site Description/Documentation Procedures

The biological sampling veterinarian will verify the correct location and validity of the particular sampling site using those site evaluation criteria, etc., discussed previously for soil and crop sampling (subsections 2.2.3.3, 2.2.3.5). Once approved, the veterinarian or field assistant will complete Parts A and B of the site description form, Tablee 4.5-13. If the particular livestock site is not designated also for soil-crop sampling, then Parts C through F (of this form) will be completed as possible or appropriate.

In addition, each sampler or team leader will be provided initially with a Field Worklog. A new page will be used for each herd or band sampled. The worklog form proposed for this project has been modified slightly from that recommended by Dr. Maurice Hull for use in the East Helena smelter study, (Dollhopf et al. 1984, Figures 18-19). The resulting form is shown in Table 4.5-14 of this report. As each sampler will possess the master copy of the particular weather-proof worklog, it is strongly recommended that each day's records be photocopied upon completion of the chain-of-custody procedure. Thus, a "back-up" copy of all records will be kept at the sample bank and will be available in the event of loss of the master copy.

The worklog(s) will be completed on a daily basis and be filed in project offices for use by the crew leader(s) and by the project leader (for preparation of progress reports, etc.). These records will be reviewed by the project manager at least weekly to assure adherence to the above plan.

Sample Acquisition Protocols

Whole blood and hair-wool sampling methodologies will follow those developed for the East Helena smelter-related livestock assessment program, (Dollhopf et al. 1984). These methods are described in detail in Appendix 4.4.16.

2.2.3.8 Livestock Tissue Analytical Methods

The number of livestock sampled, number of samples taken per animal, and analytical treatment schemes are summarized in Table 2-18. Livestock tissue analytical methods are described in Appendix 4.4.17.

2.3 WARM SPRINGS PONDS LIFE SPAN STUDY

The investigation to determine the life span of the Warm Springs Pond will rely on other investigations for the generation of the water quality data necessary for a life span analysis.

Loading factors of precipitates and sediments will be calculated from data developed by the surface water investigation. A bathymetric survey will be required for Ponds 2 and 3. A professional survey of existing pond bottom topography will be performed so that a profile of the existing ponds can be used to accurately determine the useful remaining volume. Density testing and constituent testing of precipatates and sediments will be required to determine storage potential and chemical potential. A review of past, current, and planned operating procedures for the Warm Springs Ponds will be necessary to determine the effectiveness of current operating procedures and future procedures. A working model of the entire treatment system incorporating mass balance calculations for sediments and major chemical species, precipitate composition and density will be constructed. A sensitivity analysis of the

TABLE 2-18.--SUMMARY OF RECOMMENDED ANALYTICAL REQUIREMENTS FOR LIVESTOCK SPECIES

Phase No.[a]	No. Animals Sampled	No. Samples Per Animal[b]	Analytical Treatment Scheme[c]
1	Re: "affected" sites-- • 30 head of cattle • 5 head of sheep • 2 head of horses Re: "control" sites-- • 3 head of cattle • 2 head of sheep • 2 head of horses	One triplicate sample of hair or wool; one quadruplicate sample of blood.	Re: "affected animals"-- • Determine initially total As, Cd, Cu, Pb, and Zn concs. in blood plus hair or wool. • If "heavy metal" contamination is significant, analyze animal tissues (e.g., meat, liver) or products (e.g., milk) that could be consumed by humans. Re: "control animals"-- • Determine total As, Cd, Cu, Pb, and Zn concs. in blood plus hair or wool. • If possible, analyze animal tissues (e.g., meat, liver) and/or product (e.g., milk) that could be consumed by humans.
2	Re: "affected sites"--continue reconnaissance-level investigations using the Phase 1 sample numbers (per species). Re: "control sites"--acquire 2 extra head of cattle, and one additional sample each for sheep and horses.	Ditto.	Re: "affected animals"--utilize same analytical scheme as presented above. Re: "control animals"--utilize same analytical scheme as presented above.

TABLE 2-18.--SUMMARY OF RECOMMENDED ANALYTICAL REQUIREMENTS FOR LIVESTOCK SPECIES (CONTINUED)

Notes: a) Phase I is tentatively scheduled for the period September 3, 1984 through December 28, 1984. Phase II is tentatively scheduled for the period June 17, 1985 through September 27, 1985.

b) Does not include field blanks.

c) "Heavy metal" contamination in presently extant livestock populations has to be documented prior to performing human health-related analyses of meat, milk, etc. Thus, analytical methodologies for these latter (animal) products were not addressed in the work plan, as such efforts may be premature (or unneccessary in terms of completing endangerment assessment efforts).

variables affecting lifespan of the ponds as a treatment facility will then be performed. The identification and prediction of important variables over time together with the requisiste physical and chemical data will then be used to evaluate the useful life of the existing ponds for treating Silver Bow Creek waters.

Specific new activities required for this study are the bathymetric survey (described above), and possibly additional sediment and precipitate sampling. However, prior to implementation of the core sampling program, a review of existing literature (i.e. James 1980; and James and Searle 1981; and James and Peterson 1983) will be performed to determine if this data meets the project QA requirements and the investigation modeling requirements.

Past, current, and future operation of the Warm Springs ponds will be identified through discussions with the appropriate AMC personnel.

2.4 DATA ANALYSIS

The following text describes those data analysis activities recommended for summarizing, comparing, and evaluating the data generated by the remedial investigations.

2.4.1 Hydrogeologic Data Analysis

Data analysis will be on-going throughout the duration of the Remedial Investigation, but final analyses will await completion of

Phase II field activities and receipt of all laboratory results. All data will be compiled, summarized, and organized on a proven computerized data management system to assist subsequent statistical analyses, graphical presentations, or computer modeling of specific problem sites.

Data analysis will evaluate and distinguish between natural and man-caused water quality variations and degradation. This will be a necessary first step in delineating the severity and extent of attributable impacts. Due consideration will be given statistical confidence and significance. The most reliable, comprehensive, and state-of-the-art quantitative techniques will be used to attain an accurate description of conditions within individual investigative areas and the entire study area (see Section 4.0).

Analyses will allow description of changes in type, as well as variations in degrees of water quality degradation throughout the study area. This should be accomplished both at-a-station and on the basis of downstream trend analysis.

2.4.2 Biological Investigations - Data Analysis

2.4.2.1 Aquatic Communities

Fisheries

Analysis of the data generated by the bioassay study is described in

subsection 2.2.1.5 - Area V; Clark Fork River. Analysis of the data generated by the Warm Springs Ponds Fish Tissue Study is described in the Appendix.

Algae

The objective of algal data analysis will be to determine the role algae play in "metal" transport or removal within the Silver Bow Creek-Upper Clark Fork System. Algal community species counts will be compared using number of taxa, and dominant taxa. Cluster analyses will be used if appropriate (Pickett 1978). Diversity values will be compared using statistical tests such as the analysis of variance and the Student-Newman-Keuls range test. Chlorophyll *a* estimates will be compared temporally and longitudinally. The metals which are found absorbed in algae will be related to chlorophyll *a* estimates. Chlorophyll *a* estimates will be used to estimate the total removal capacity of the system, and will be related to ambient metals values. The results of nutrient analyses will be related to the chlorophyll *a* estimates to determine the effect that fertilization or reduction in sewage input would create.

2.4.2.2 Natural Terrestrial Communities

Floral Communities

Data analysis of the information generated by the vegetation mapping

should be aimed at answering the following questions.

- How many acres of flood plain land have been affected by contamination of Silver Bow Creek and the Upper Clark Fork River?

- Where are the potential reclamation sites, borrow sites, and potential sources of reclamation/revegetation materials?

- What species of plants appear to be contamination tolerant, where are they located, and how abundant are they?

The answers to these questions can be answered by: measuring areas on the maps; comparing relatively undisturbed areas (the Summit Valley tributaries) with disturbed areas; and examining species composition of disturbed area mapping units.

Faunal Communities

Analysis of data generated by the Warm Springs Ponds Waterfowl Survey will be performed as described in Appendix 4.4.11.

2.4.2.3 Agricultural Systems

The data analysis approach for agricultural-related information is described in Appendix 4.4.18.

2.5 REPORT PREPARATION

2.5.1 Hydrogeologic Investigation

Two reports will be prepared: 1) an interim report to be completed at the end of Phase I investigations; and 2) a final report to be submitted at project end. Both reports will include all necessary text, figures, tables, and maps pertinent to the project and phase objectives, scope of work, and tasks. Analytical assumptions, interpretations, and conclusions will be described, and recommendations for additional analyses, if warranted, will be included.

The interim Phase I report will contain or summarize all relevant data collected to date. The final project report will contain and append all collected water quality data, drilling logs, streamflow measurements, and well completion information.

It is anticipated that the final project report will contain at least six volumes: one for each investigative area or reach of Silver Bow Creek or Clark Fork River and a summary volume to describe overall conditions within the study area. The severity and extent of impacts attributable to individual sites will be ranked within the total study area and within each investigative area.

2.5.2 Biological Investigations

2.5.2.1 Aquatic Communities

The report prepared as a result of the aquatic communities investigation will describe the aquatic communities found within each study area subunit. The report will present statistics, charts, and tables to show relationships between water chemistry and aquatic community species' occurrence, density, biomass production (algae), and tissue concentrations of contaminants.

2.5.2.2 Natural Terrestrial Communities

Floral Communities

Data generated by from this aspect of the remedial investigation will be presented in the following manner.

- All maps and graphic data presentation originals will be done on mylar or equivalent drafting media.
- The tables will be constructed to list the plant species occurring in each vegetation mapping unit.
- Text will be prepared that discusses the methods used, results, conclusions, and recommendations (for remedial action).

Faunal Communities

The report prepared as a result of the natural terrestrial community investigation will utilize statistics, charts, graphs, and tables to describe relationships between water chemistry and tissue concentrations of contaminants in waterfowl. It will attempt also to evaluate the hazard to humans from consuming Warm Springs Ponds waterfowl.

2.5.2.3 Agricultural Systems

Preparation of the Draft (Phase II) Report

The preparation of the draft report will be initiated towards the end of the laboratory analysis program. The report will probably have three major sections: an introduction, study results, and a conclusions/recommendations section. The introductory section will include the following: 1) a reiteration of the problem: 2) presentation of contractual scope of work; and 3) incorporation by reference the methodologies discussed in the Work Plan. The results section will be initiated with a general discussion of the study area's patterns of alluvial soil associations and mill tailings plus irrigated crops and native rangeland. These patterns will be related to the observed pattern of adversely affected irrigated croplands and livestock utilizing water from Silver Bow Creek or Upper Clark Fork River. These relationships will be shown by the sampling strata/problem area overlays on the topographic base

"master sampling" map(s). The subsection pertaining to soils will be divided into presentation of field observations (e.g., site descriptions) per "problem type" or cropland type, and presentation of the respective laboratory data.

The subsection presenting the results of the crop and rangeland studies and livestock studies will be presented also in terms of field observations and laboratory data. Such information will include both clinical (toxic metal) syndromes observed in the field, and chemical analyses of various tissue types.

The conclusions will appraise the variability of site-specific contaminant and soil/cropland conditions, and how such variability may affect the formulation of soil/cropland/livestock rehabilitation programs.

2.5.3 Warm Springs Ponds Life Span Study

The report prepared by the Warm Springs Ponds Life Span Study will present the pertinent data (i.e., water quality, survey summaries, etc.) and the calculations performed with the data. This report will reach conclusions regarding the expected life span of the ponds as treatment facilities.

3.0 EVALUATION AND JUSTIFICATION

3.1 HYDROLOGICAL

3.1.1 Surface Water

An extensive evaluation was completed to document all data and associated information relative to the surface water regime within the project study area. Included in this review were all available surface water quality and quantity data for the Silver Bow Creek drainage and the upper Clark Fork River Valley. These data were synthesized to indentify surface water contamination, as well as areas where contamination is suspect but has not been described.

Based on a review of available literature, it is apparent that surface water degradation in the study area is due primarily to the following: tailings deposits in and adjacent to Silver Bow Creek and Clark Fork River; inflow of contaminated ground water to the streams; various point source pollutant discharges to the drainages; and, possibly input from natural sources.

The following is an evaluation of the surface water system within the Silver Bow Creek / Clark Fork River study area. Documentation is presented for portions of the system in which water quality and/or quantity data have been collected. In areas where gaps in existing data are identifiable, justification is provided for gathering additional information such that an understanding of the

surface water system and its interrelationships with other physical processes is attainable.

3.1.1.1 Area I: Summit Valley to Whiskey Gulch

Major surface water features in Area I include Silver Bow Creek above and below Butte Operations and its major tributary, Blacktail (Bell) Creek (see Exhibit 1). Other surface water systems in Area I include ephemeral or intermittent tributaries to Blacktail Creek and Silver Bow Creek and several springs located near Rampart Mountain.

Blacktail Creek

An evaluation of Blacktail Creek water quality was completed by MDHES (Montana Department of Health and Environmental Sciences) and MBMG (Montana Bureau of Mines and Geology). A total of nine samples were collected at various sites along the stream between June 1972 and September 1977. One additional sample was collected in April 1983. As well, Anaconda Minerals Company (AMC) collected several samples from the mouth of Blacktail Creek between July, 1976 and August, 1982, primarily to analyze metals concentrations.

MBMG initiated a water quality sampling program on Blacktail Creek in October, 1983, in conjunction with its study of the effects of rising water levels in the Berkeley Pit. One site is located approximately six miles upstream from the mouth of Blacktail Creek

near Eagles Nest Campground (Duaime 1984). At the same time, the U.S. Geological Survey (USGS) was contracted by MBMG to install and monitor a stream-flow gaging station at this site. The gaging station (Number 12-3228.00) utilizes a mercury manometer and associated rating curves to attain a continuous record of stream discharge (Shields 1984). Although a continuous record of streamflow is currently being obtained, collection of water quality samples has been sporadic (Duaime 1984).

Evaluation of available water quality data for Blacktail Creek indicates the water is generally a good quality, calciumbicarbonate type, with low to moderate concentrations of metals. Factors that could periodically affect the quality of Blacktail Creek include a number of Butte-Silver Bow storm drains that discharge to the stream and septic systems of households adjacent to the stream. The influences of these factors on Blacktail Creek is poorly understood.

Available data characterize the quality of the water in Blacktail Creek to some extent. These data were typically derived by grab samples which represent the quality of water at a point in time. No attempt has been made to collect or to evaluate surface water data from Blacktail Creek and Silver Bow Creek synchronously. This type of sample collection is requisite to an understanding of the impact of Blacktail Creek on the Silver Bow Creek drainage. Previously collected water quality data are also not verifiable owing to the general lack of proper sample custody documentation and the lack

of any sample quality assurance/quality control plan.

Additional characterization of the quality and quantity of Blacktail Creek is necessary. This is because of the lack of data available to correlate the impact of the stream on Silver Bow Creek as well as the questionable validity of historic surface water data.

Silver Bow Creek

Silver Bow Creek in Area I is dissected by mining activities associated with AMC's Butte Operations. The reach of the stream above mining activities remains relatively undisturbed, while the stream channel in and immediately below mining disturbance has been altered greatly and is virtually indistinguishable. The Butte Metro Storm Drain replaces the historic Silver Bow Creek channel from Butte Operations to its confluence with Blacktail Creek.

Silver Bow Creek water quality data below Butte Operations is generally for samples collected from the Butte Metro Storm Drain and the Clear Water Ditch. Discussion and evaluation of data collected are contained in Section 3.1.2.

Silver Bow Creek below its confluence with Blacktail Creek and within Area I has been physically altered in several reaches. These reshaped reaches include a site near a manganese stockpile area adjacent to Montana Street and the Colorado Tailings area (see Exhibit 1). The stream reach in the vicinity of the manganese stockpile has been

channelized between large columns of smelter slag. Downgradient of the manganese stockpile area, Silver Bow Creek has been diverted north of and around the Colorado Tailings. Below the Colorado Tailings area, the stream follows approximately its natural course to the end of the Area I study unit.

Existing surface water data for the reach of Silver Bow Creek between its confluence with Blacktail Creek and the Area I boundary at Whiskey Gulch consist of quality and quantity information presented by Fox (1972), Hydrometrics (1983e), and MDHES (unpublished data). MBMG, in conjunction with the USGS, established a sampling/gaging station (#12323000) below the Colorado Tailings in October, 1983. Previous sampling sites within the reach are located at various sites and samples were obtained at various times. Historic water quality data for this reach of Silver Bow Creek are extremely variable owing to the influence of Weed Concentrator discharges on the surface water system. Prior to 1972, untreated water was discharged from the concentrator to Silver Bow Creek via the Butte Metro Storm Drain.

Samples collected prior to 1972 contained very high concentrations of metals, high specific conductivity, and low pH values (Fox, 1972). After 1972, water samples collected in this reach of Silver Bow Creek indicate that concentrations of metals were reduced considerably and pH values were higher (MDHES, unpublished data). Following analysis of existing water quality data collected by AMC, Hydrometrics (1983e) concluded that a poor to fair correlation

exists between flow and total copper and zinc loads in this reach of Silver Bow Creek. This variability is probably due to sample collection time and place in relation to the periodic discharges of treated water from the Weed Concentrator.

Potential impacts to Silver Bow Creek in the lower reaches of Area I currently include: storm runoff from disturbed areas in uptown Butte; a seep identified in the vicinity of the manganese stockpile area; PCP contamination in the vicinity of Montana Pole and Treating Plant; the Butte sewage treatment plant; the Colorado Tailings; isolated tailings deposits along the stream below the Colorado Tailings railroad ballast from rail lines north of the stream; and ground water discharge to the stream. Discharges from the Weed Concentrator were discontinued with suspension of mining operations in Butte in 1983.

Further definition of the surface water regime is necessary from the Butte Metro Storm Drain - Blacktail Creek confluence to the downgradient boundary of Area I at Whiskey Gulch. Justification for obtaining additional surface water flow and quality data includes: the need to obtain synchronous samples to better define the inter-relationships between the physical systems in the area, and the need to better define surface water - ground water interrelationships. Since suspension of mining in Butte and the subsequent discontinuance of discharge from the Weed Concentrator, little surface water data have been collected to characterize this changed regime. Little attempt has been made to characterize the influence of all point source discharges in this reach on the Silver Bow Creek system.

Additional surface water data needed in the area include synchronous, detailed water quality and quantity information at sites above and below the Colorado Tailings. The MBMG/USGS gaging station located below the Colorado Tailings will suffice as the downstream flow monitoring and sampling site. Upstream stations will be sites selected for routine sampling. Detailed seepage runs are necessary to quantify gaining and losing reaches in the stream. These data, in conjunction with information collected at sampling and flow monitoring stations for the Butte Metro Storm Drain and Blacktail Creek, should be sufficient to describe the surface water regime in the lower reaches of Area I.

If significant changes in water quality are found between sampling stations, a more detailed evaluation phase of point sources and other factors between sites should be undertaken.

3.1.1.2 Area II Whiskey Gulch to Head of Canyon

Major surface water features in Area II include Silver Bow Creek, a major tributary to Silver Bow Creek (Browns Gulch), and numerous ephemeral tributaries to the above streams. The Area II reach is severely impacted by thick tailings deposits adjacent to Silver Bow Creek. Other influences on the surface water regime in the area include: flow in Silver Bow Creek from Area I; domestic sewage effluent from small communities adjacent to Silver Bow Creek; and possibly the Stauffer Chemical Plant.

Browns Gulch

Browns Gulch is the major tributary to Silver Bow Creek in Area II and joins the stream near Ramsay. Irrigation is prominent in the lower portion of the watershed during the summer months. Browns Gulch is often dry at the I-90 highway crossing near Ramsay during the irrigation season and during the winter low flow period (January through early March) (Botz and Karp 1979).

Water quality sampling of Browns Gulch has been limited to one sample collected in 1976 and four samples collected between 1972 and 1973 by MBMG. MDHES collected a few samples from Browns Gulch in its upper reaches and one sample at its mouth in April 1983. AMC collected several surface water samples from lower Browns Gulch in the early 1970's (Hydrometrics 1983e).

Available data suggest Browns Gulch is a high quality stream that can be characterized as a slightly alkaline, calcium-bicarbonate water with low concentrations of dissolved solids, sulfate, and metals. MDHES (1983) suggests, however, that Browns Gulch is a major contributor of total suspended solids to Silver Bow Creek. Reasons for these conflicting conclusions are unknown.

Additional data are necessary to characterize Browns Gulch water quality particularly in relation to its suspended sediment load. To evaluate the character of Silver Bow Creek below its confluence with

Browns Gulch, it will be necessary to obtain synchronous flow measurements and water quality information from Browns Gulch and Silver Bow Creek.

These data are necessary in mass balance and mass loading calculations. An abbreviated parameter list will probably suffice at this site.

Silver Bow Creek

Silver Bow Creek in Area II is influenced greatly by extensive tailings deposits adjacent to and in the stream. Associated impacts include: increased sedimentation and erosion; inflow of highly mineralized ground water; and seasonal flushing of surface salts from the tailings to the stream. Other factors affecting this surface water regime in Area II include: domestic waste effluent; input of sediment from ephemeral drainages tributary to Silver Bow Creek and possibly impacts caused by activities at the Stauffer Chemical Plant. Evaluation of these potential contaminant sources is contained in Section 3.1.2.

Surface water data for Silver Bow Creek in Area II have been described by Hydrometrics (1981b and 1983e), Fox (1972), Peckham (1979), and MDHES (1983). Water quality data suggest Silver Bow Creek is degraded from the upper boundary of Area II to its lower boundary. This is probably due to the influence of the extensive tailings deposits adjacent to the stream (Hydrometrics 1983e). Botz and

Karp (1979) suggest Silver Bow Creek does not lose or gain any significant quantity of water in this reach.

Available water quality data indicate a wide variation in metal and other parameter concentrations, when comparing samples collected prior to 1972 to samples obtained after 1972 when treatment of concentrator discharge began. Data prior to 1972 indicate Silver Bow Creek water contained very high metals concentrations and exhibited high specific conductivity and low pH values (Fox 1972). Surface water data collected subsequent to 1972 reveal a marked improvement.This is due to the installation and operation of primary and secondary treatment systems at the Weed Concentrator beginning in September, 1972. Surface water data collected in 1972-73 and 1975 suggest relatively small increases in metals levels from upstream to downstream stations in Silver Bow Creek although an analysis of actual loadings indicates that metals increase in quantity (Spindler 1976). Peckham (1979) confirms the finding of downgradient increases in metals loads in Silver Bow Creek and attributes the increases in metals loads to additions from tributary sources and from ground water discharges to Silver Bow Creek near Ramsay.

MDHES (1983)conducted an intensive water quality survey along Silver Bow Creek on April 27 and 28, 1983 to assess the impact of the discontinued of discharge from AMC's Butte facility in February 1983. The survey suggests metal and sulfate loads increase downstream and are due to the extensive tailings deposits adjacent to Silver Bow

Creek. These conclusions are qualified in that they represent a single sampling episode and may not be applicable to different flow conditions.

It is recommended that detailed surface water data be collected in Area II over at least one calendar year. This recommendation is based on review of available data which suggest that features present in Area II may currently be responsible for much of the water quality degradation of lower Silver Bow Creek.

Data necessary to characterize the surface water regime in Area II include the establishment of permanent gaging stations in the Nissler/Silver Bow area and another west of Miles Crossing near the mouth of a bedrock constriction (see Exhibit 1). These stations, complimented with data collected from USGS station number 12323000 below the Colorado Tailings, will produce a continous record of Silver Bow Creek flow above, within, and below the major tailings deposits in Area II.

In addition to the permanent recording stations described above, four surface water sampling sites should be established on Silver Bow Creek in Area II; the recommended locations include two between each of the permanent gaging stations. In this manner, detailed comparisons between sampling sites can be made to characterize inputs to the surface water system within Area II.

Sample analyses should be conducted for a suite of chemical parameters such that all potential sources of water quality degradation are adequately described. If, after a few sampling episodes it is determined that certain chemical parameters are insignificant to the characterization of Silver Bow Creek water quality, analyses of these parameters can be discontinued.

Seepage runs should be conducted throughout Area II to identify surface water - ground water interrelationships. Seepage runs are important in mass loading and mass balance calculations in that the results can be used to isolate inputs to the surface water system. Seepage runs should be conducted during low flow periods at established sampling sites, in addition to other locations between these sites. Both water quality and quantity information should be collected during the seepage runs.

3.1.1.3 Area III - Head of Canyon to Warm Springs Ponds

The primary surface water features in Area III include Silver Bow Creek and major tributaries, including German Gulch, Mill Creek, and Willow Creek. Numerous ephemeral drainages tributary to these streams are also present. Silver Bow Creek in Area III flows through a volcanic bedrock canyon before entering the broad Deer Lodge Valley near Fairmont Hot Springs (see Exhibit 1). Isolated point bars of tailings are present within the canyon. More extensive yet thinner deposits of tailings are present between Fairmont Hot Springs and Warm Springs Ponds.

German Gulch

The USGS maintained streamflow gaging station number 12323500 near the mouth of German Gulch Creek from 1955 to 1969, although water samples were not collected. Irrigation withdrawals are common during the summer months along lower German Gulch; these actions alter the annual hydrograph during this time period.

Water quality data for German Gulch consist of analyses presented by Fox (1972), Hydrometrics (1983e), MDHES (unpublished data), and Beuerman and Gleason (1978). Most of the analyses were conducted for examination of metals and nutrient concentrations. Based on these existing data, German Gulch Creek water is a high quality, hard, calcium - bicarbonate type with low concentrations of dissolved solids, sulfate, and metals.

Additional surface water data needs from German Gulch Creek include obtaining a record of water quality and quantity such that comparisons and evaluations can be made in relation to concurrent data collected from Silver Bow Creek. Data generated will be used to determine mass balance and mass loadings to Silver Bow Creek in Area III.

Mill and Willow Creeks

Few flow records are available for either Mill Creek or Willow Creek. The prominence of irrigation along both streams causes the flow to

be very small near their confluence from July to September. Both streams appear to lose water in their upper reaches and gain flow in the vicinity of their confluence (Botz and Karp 1979).

Unpublished data generated by MDHES indicate water quality in Mill Creek and Willow Creek near the Town of Opportunity is good; the water is characterized as slightly saline with low sulfate and metals concentrations and low specific conductivity.

Mill Creek and Willow Creek are directed around the Warm Springs Ponds on the west side via the Mill - Willow Bypass. Botz and Karp (1979) examined the quality of water in the bypass and concluded that there is a significant increase in sulfate concentration along the bypass from its beginning to its confluence with Warm Springs Pond 2 discharge. This phenomenon was attributed to ground water inflow from Pond 2. Water quality data collected by MDHES (1983; unpublished data) at the mouth of the Mill - Willow Bypass supports the contention that sulfate concentrations are elevated when compared to data collected from Mill Creek and Willow Creek above their confluence.

Additional surface water data are necessary to characterize Mill Creek, Willow Creek, and Clark Fork River. Surface water sampling sites will be located at the head of the bypass and just upstream from its confluence with Pond 2 discharge (See Exhibit 1). In addition, a seepage run should be conducted on the Mill-Willow Bypass during low flow conditions to ascertain any ground water inputs

to the bypass by adjacent pond systems. These data will allow a complete evaluation of the surface water regime in this area and aid in characterizing potential impacts to the upper Clark Fork River.

Silver Bow Creek

Silver Bow Creek in Area III is potentially influenced by extensive, thin tailings deposits in and adjacent to the stream from near Fairmont Hot Springs to the Warm Springs Ponds and by irrigation activities in the southern Deer Lodge Valley. Discussion and further evaluation of these potential impacts are contained in Sections 3.1.3 and 3.2.3, respectively.

Available surface water quality data for Silver Bow Creek in Area III are described by Beuerman and Gleason (1978), Peckham (1979), Hydrometrics (1983e), MDHES (1983), MDHES (unpublished data), and Fox (1972). These data suggest great differences in water quality from prior to 1972 versus after 1972 when discharge treatment facilities were installed and inplemented at the Weed Concentrator in Butte.

AMC data reported by Hydrometrics (1983e) indicate that a small input of metals occurs in the reach of Silver Bow Creek flowing through a narrow canyon (approximately from the western boundary of Area III to near Fairmont Hot Springs). MDHES (1983) report significant increases in sulfate and metals concentrations in this same reach. The probable source of these metals is flood plain tailings deposits

near Miles Crossing (Area II) and in the canyon. Silver Bow Creek water quality near the Gregson Bridge (Exhibit 1) is variable, but it is apparent that it has improved significantly since early 1983 when concentrator discharge was discontinued in Butte. Based on data presented by MDES (1983), Silver Bow Creek in the southern Deer Lodge Valley exhibits elevated concentrations of total and dissolved zinc and copper, although sulfate concentrations have dropped considerably compared to earlier water quality data. Surface water data collected from sites further downstream, yet above the Warm Springs Ponds, indicate little change occurs in water quality over this reach of stream, although the creek may lose some flow (Hydrometrics 1983e).

Although no continuous record of flow exists for Silver Bow Creek in Area III, Botz and Karp (1979) report a flow of 3000 cfs in the vicinity of the upper pH shack at Warm Springs Ponds in the early 1930's. The capacity of the headgate at the upper pH shack is reported to be about 900 cfs. Flows in the stream occasionally exceed this amount. AMC constructed a bypass system in the late 1960's to route large flows around the Warm Springs Ponds.

Additional surface water data are justifiable for Silver Bow Creek in Area III owing to the lack of information available since cessation of discharge of concentrator effluent in Butte. It is apparent from evaluation of MDHES (1983) data that the surface water regime in Area III has changed significantly since 1983.

Because of this, a permanent gaging station should be constructed either near the Highway 10-A bridge or near the Stewart Street Bridge (See Exhibit 1). In addition, a sampling site should be located near the Fairmont Bridge. These sites should be sampled monthly for at least one calendar year to characterize flow and water quality in Area III.

3.1.1.4 Area IV, Warm Springs Ponds

James and Searle (1981) and James and Peterson (1983) evaluated the Warm Springs Ponds system for metal removal effectiveness. These studies concluded that although the Warm Springs Ponds are nearly filled with solids, the pond system effectively protects the Clark Fork River from metals contamination during most flow conditions and seasonal variations. The future effectiveness of the pond system will depend on the rate the remaining available pond volume is filled by material removed by water treatment (James and Peterson 1983). No recent data has been collected on the solids loading to the ponds, hence, it is difficult to predict the effective life of the ponds or to design changes in the pond system necessary to prolong their effectiveness.

The major source of solids loading in the Warm Springs Ponds is Silver Bow Creek. A diversion structure located near the inlet to the ponds, allows peak flow to be diverted around the pond through the Mill-Willow Bypass. It has been estimated that the diversion

structure and bypass ditch are capable of handling the 100-year flood peak of 3600 cfs without failure. However, the diversion structure and bypass will not handle the Probable Maximum Flood (PMF) estimate of 130,495 cfs. Such a PMF would result in failure of the entire Warm Springs Pond system (Hydrometrics 1983f). Studies are recommended to determine the future operating life of the ponds.

3.1.1.5 Area V - Clark Fork River

Major surface water features in Area V include Clark Fork River, major tributaries of Clark Fork River (Warm Springs Creek and Warm Springs Pond 2 discharge) and numerous minor tributaries. These drainages are shown on Exhibit 1. A discussion and evaluation of surface water data for Warm Springs Pond 2 discharge is contained in Section 3.2.1.4.

The Clark Fork River in Area V is potentially affected to some extent by: thin tailings deposits adjacent to and in the River; agricultural activities in the Deer Lodge Valley; domestic waste discharges from several communities in the area; and Warm Springs Pond discharges. As well, impacts in drainages tributary to Clark Fork River may degrade Clark Fork River to some degree.

Warm Springs Creek

Warm Springs Creek water has historically been used for irrigation

and by the Anaconda Minerals Company (AMC) for industrial purposes. Maximum flows typically occur during spring runoff, and minimum flows occur in late summer and mid-winter. During the irrigation season (approximately July to September), almost the entire flow of the stream is used for irrigation (Botz and Karp 1979). Withdrawals from Warm Springs Creek by AMC have been discontinued owing to closures of the Anaconda Smelter and Butte Operations.

Botz and Karp (1979) report Warm Springs Creek loses water as it enters the Deer Lodge Valley but appears to gain water in its lower reaches. Beuerman and Gleason (1976) conducted a seepage run at several sites along Warm Springs Creek in 1976. Their results support conclusions stated by Botz and Karp (1979). The USGS began maintaining a gaging station (number 12323770) in October, 1983 near the mouth of Warm Springs Creek, and several miscellaneous flow measurements were made at this site from 1972 - 1974 (USGS, unpublished data). Other flow data include only measurements obtained in conjunction with isolated water sampling events.

Available water quality data for Warm Springs Creek include information described by Botz and Karp (1979), U.S. EPA (1972), MDHES (unpublished data), and MDHES (1983). Based on available data, Warm Springs Creek can be characterized as slightly alkaline, hard water with low concentrations of sulfate and total and dissolved metals. Data presented by Botz and Karp (1979) indicate an inverse relationship between sulfate concentrations and flow in Warm Springs Creek, possibly owing to irrigation return flow impacts.

Additional data needs for Warm Springs Creek should be limited to collecting quality and quantity information at the recently installed USGS gaging site located near the mouth of the drainage. Negotiations should be conducted with the USGS such that continuous records of flow are made available in a timely manner and water sampling schedules are coordinated with samples obtained elsewhere in the study area.

Clark Fork River

The Clark Fork River in Area V has been the subject of numerous investigations over the last 15 years. U.S. EPA (1972) conducted a water quality study of the upper Clark Fork River. McLean (1960) investigated heavy metal contamination of the stream from below Warm Springs Ponds to Missoula. Casne and others (1975) prepared a water quality inventory and management plan for the upper Clark Fork River basin. Botz and Karp (1979) reviewed sulfate data in the upper reaches of the Clark Fork. James (1980) reviewed water quality data for the River. MDHES (1983) collected grab samples at three sites in the upper Clark Fork River in its analysis of sulfate and metals loads, and Hydrometrics (1983g) reviewed AMC data in its analysis of the stream.

The USGS has operated several gaging stations on the Clark Fork River in Area V during the last several years. These stations include : Number 12323750, located about one quarter mile below Warm Springs

Ponds, operated 1972 - 1979; Number 123238.0, located approximately two miles below Warm Springs Ponds, operated 1971 - 1973 as a non-continuous, miscellaneous measurement site; Number 1234200, located at Milwaukee Avenue Bridge in Deer Lodge, operated 1978 to present; and Number 12324680, located near the community of Gold Creek, operated 1977 to present.

Based on flow data from USGS (1982), greatest flows typically occur in Clark Fork River during May through July, while smallest flows usually occur during August and September when irrigation withdrawal is greatest, and during January when winter base flow predominates. The USGS did not collect water quality data at these sites except for the gaging station at Deer Lodge where temperature data are collected.

Existing Clark Fork River water quality data are variable owing to activities upstream at the Anaconda Smelter and Butte Operations. When comparing the data, however, it is apparent that water quality gradually improves downstream. Prior to 1972 when effluent treatment facilities were not in operation at the Weed Concentrator, Clark Fork River water was extremely hard and exhibited high concentrations of sulfate and both total and dissolved zinc, copper, and iron (U.S. EPA 1972). Data collected after 1972 indicate the concentrations of sulfate and metals had decreased, although the actual values remain somewhat elevated over unaffected streams.

James (1980) reported arsenic and zinc concentrations in the upper

Clark Fork River to be seasonal in nature; highest values occurring during the winter months. He also suggested the Warm Springs Ponds have little effect on sulfate loading in Clark Fork River because sulfate loading has a direct relationship with streamflow. MDHES (1983) refutes this conclusion by suggesting sulfate-laden ground water may be infiltrating from the Warm Springs Ponds causing elevated concentrations downstream. Botz and Karp (1979) report sulfate loads downstream of the Warm Springs Ponds are heavily dependent on flow regulation in Pond 2. They also conclude that sulfate, at concentrations present in Clark Fork River, present little, if any, adverse environmental impacts.

MDHES (1983) collected water quality samples from Clark Fork River in April 1983, after discharge of concentrator effluent ceased in Butte. Analytical data from these samples indicated water quality has improved to some extent compared to data collected prior to 1983. Conclusions drawn by MDHES (1983) indicate most of the metals and sulfate ion in Clark Fork River below Warm Springs Ponds came from Warm Springs Ponds, not from Mill, Willow, or Warm Springs Creek. A significant increase in sulfate and total copper loads was also suggested from Clark Fork River below Warm Springs Creek to Clark Fork River at Deer Lodge.

Additional surface water data for upper Clark Fork River are necessary in Area V owing to the lack of adequate information to describe the

surface water regime in a post-mining environment. Based on available data, it is apparent Clark Fork River water quality is evolving and has changed significantly over the last several years.

To document these changes, flow and quality data should be collected on the river at several sites below Warm Springs Ponds. Sampling stations should be established at various locations on the Clark Fork River between Warm Springs Ponds and Garrison Junction. As well, provisions should be made with the USGS to use data collected at its station located in Deer Lodge (Number 12324200).

Selected index parameters should be analyzed for samples collected at these sites. Sampling should be conducted at least during spring runoff and at sufficient sites to document areal changes in surface water quality along the river.

3.1.2 Point Sources

3.1.2.1 Area I Summit Valley to Whiskey Gulch

Most of the known point source discharges in Silver Bow Creek-Clark Fork River study area are located in Area I. These point sources can be categorized into specific types including: stormwater, domestic, and industrial. Each category is addressed below.

Stormwater

For at least ten years investigators have pointed to stormwater runoff in and near Butte as a major contributor of metals to Silver Bow Creek. These investigators based their conclusions on the fact that runoff water from most inactive mines and waste dumps in the uptown Butte area reach Silver Bow Creek via the Metro Storm Drain or a direct outfall to Silver Bow Creek (Hydrometrics 1983e).

The nature of the effect on Silver Bow Creek by stormwater runoff has changed recently owing to the 1983 shutdown of the Anaconda Minerals Company (AMC) Butte Operations. It may be reasonable to expect that stormwater runoff presently provides a higher percentage of contaminants load to Silver Bow Creek than ever before.

One water quality survey has been performed in Area I since the AMC shutdown in Butte in early 1983. This survey was conducted by MDHES (1983) on April 27 and 28, 1983. During this study the Metro Storm Drain was sampled just above its confluence with Blacktail Creek near the Kaw Avenue Bridge. MDHES (1983) found the stormdrain to be a major source of metals contamination to Silver Bow Creek.

The effects of other stormwater in the Butte area that reach Silver Bow Creek directly as a point source or via Blacktail Creek are not well known owing to the lack of pertinent water quality data.

Domestic

The major point source contributor of domestic origin in the Butte area is the Metro Sewage Treatment Plant. A great deal of water quality data have been collected at the Sewage Treatment Plant discharge by regulatory agencies as well as by the City of Butte. Investigators have come to different conclusions about the effects of the Sewage Treatment Plant on Silver Bow Creek. James (1980), using grab sample data of previous investigators, concluded that the Sewage Treatment Plant effluent is a major source of metals contribution to Silver Bow Creek, particularly zinc. Hydrometrics (1983e), using Sewage Treatment Plant self monitoring data, determined that the discharge is an insignificant contributor of metals to Silver Bow Creek. Hydrometrics (1983e) based their conflicting conclusion on the fact that the self-monitoring data were flow-weighted composites and therefore were probably more accurate than grab sample analyses reported by James (1980).

Industrial

There are no permitted industrial discharges above the Warm Springs Ponds. There are, however, a number of seeps, conduits, and open channels located at various locales along Silver Bow Creek which discharge to the stream and which flow through or emanate from industrial or tailings areas. No concerted study has been undertaken to measure the influence of these sites on Silver Bow Creek.

Areas where industrial point sources are suspected and that should be investigated include the Domestic Manganese Plant seep identified by AMC (Hydrometrics 1983e) and the area adjacent to the Montana Pole and Treating Plant in which PCP contamination has been documented. Other probable industrial point sources which warrant investigation include the Clark Tailings and the Colorado Tailings.

3.1.2.2. Area II Whiskey Gulch to Head of Canyon

Stormwater

Stormwater runoff from the west side of Big Butte flows into Silver Bow Creek via Gimlet Gulch just north of the community of Rocker (Hydrometrics 1983e). One sample of this discharge has been collected (Hydrometrics 1983e). Analytical data from this sample indicate the stormwater contains significant metals concentrations and is high in suspended sediment. Owing to the poor quality of stormwater in Gimlet Gulch, further investigation is warranted to document its impact on Silver Bow Creek.

Domestic

The Town of Rocker's sewage treatment plant discharges to Silver Bow Creek. Little information is available concerning the quality or quantity of the treatment plant effluent. Because of this, the influence of treatment plant on Silver Bow Creek is unknown.

Butte Metro's Sewage Treatment Plant sludge injection site is located near Rocker. The site is located in an arid environment and runoff seldom occurs. A field reconaissance of the area should be conducted to detail any potential impacts to Silver Bow Creek by the sludge injection site.

Industrial

Peckham (1979) reported observing a seep below the Stauffer Chemical Plant near Ramsay. He also reported a discharge pipe emanating from the tailings near the Town of Silver Bow. As well, a discharge point for the pipeline from Silver Lake to Butte is located near the town of Ramsay. Water quality or quantity information is unavailable for any of the reported discharges. Further investigation of the sites is warranted.

3.1.2.3. Area III; Head of Canyon to Warm Springs Ponds

Domestic

The Anaconda Company installed underdrains beneath the Town of Opportunity about 1910. Underdrain water from the town discharges to Willow Creek. MDHES and AMC have sampled the discharge several times in recent years and significant fecal coliform has been measured (Greene 1984a). However, the overall effect of the fecal coliform on Willow Creek or the Clark Fork River system has not been determined. Because of this, further investigation of the

discharge is warranted and its impact on the area's surface water system should be assessed.

3.1.2.4. Area IV; Warm Springs Ponds

Industrial

The Opportunity and Warm Springs Pond system discharges to the Mill-Willow Bypass at the lower pH shack located near the northwest corner of Warm Springs Pond 2. Several studies have been conducted to assess the quality of water in the Warm Springs Ponds, and hence, have included an analysis of Pond 2 discharge to the Mill-Willow Bypass. These studies include: James and Peterson (1982) and James and Searle (1981) who examined in detail the effectiveness of the ponds in removing metals from influent waters; Botz and Karp (1979) who examined sulfate loads in Silver Bow Creek and Clark Fork River upstream of Drummond; Hydrometrics (1983f) who assessed Warm Springs Ponds data collected by AMC; and MDHES (1983) who performed a cursory evaluation of water quality and metals loading changes through the pond system. Other studies of the Warm Springs Ponds have been completed by Neher and Weisel (1977) and by Pagenkoph and others (1979).

Based on analysis of data described above, it is apparent that historically the Warm Springs Ponds have been effective in removing sulfate and metals concentrations prior to discharge from Pond 2. Beginning with 1982 data, there appears to be a downward trend in

both sulfate load and concentration in water eminating from Pond 2. Recent data (MDHES 1983) suggest both total and dissolved metals have followed this same downward trend. Water quality data collected since 1982, however, indicate Pond 2 discharge continues to exhibit high sulfate and zinc concentrations although the latter appears to to be more significant to overall water quality degradation.

There are many small seeps below the ponds that have not been cataloged and evaluated. Since some of these point sources reach the bypass or Clark Fork River untreated, they can have an impact on the water quality of the river. The effects of these seepages on the surface water system must be considered as part of the decision on the future of the ponds.

Additional routine water quality and quantity data are necessary to describe the impact to Clark Fork River by Pond 2 discharge. These data should be collected in conjunction with samples collected from other surface water sites in the area such that an adequate characterization of Pond 2 input to the surface water system is made. Sampling should be completed at least monthly for one year and sample analyses should be conducted to identify a variety of parameters.

3.1.2.5 Area V; Clark Fork River

Domestic

Between the Warm Springs Ponds and Deer Lodge there are three permitted point source discharges. They include the institutions at Warm Springs and Galen, and the City of Deer Lodge. Steiner (1984) reported that the legislature appropriated funds to upgrade the Warm Springs sewage system. As well, the State of Montana will soon be letting bids to upgrade the Galen System. Construction is currently underway to add additional cells and disinfection facilities to the City of Deer Lodge's system.

Self-monitoring water quality data for Deer Lodge sewer system effluent indicate acceptable levels of total suspended sediment and biological oxygen demand. A review of self-monitoring water quality data from these facilities should be conducted to document the impact of the sewage systems' effluent on Clark Fork River.

3.1.3 Ground Water

There are sporadic data on the quality and quantity of ground water within the study area. Portions of the study are have been investigated by regional ground water studies, and small areas, such as the Colorado Tailings have detailed site-specific data. But generally, the data are scarce.

3.1.3.1 Area I: Summit Valley to Whiskey Gulch

The numerous ephemeral and intermittent tributaries to Silver Bow Creek in the vicinity of Butte have small ground water systems associated with them of unknown quality and quantity. The small ground water flows in Elk Park, Horse Canyon, China Gulch and Saratoga Creeks are probably at least partically intercepted by the Clear Water Ditch. The remaining flows enter AMC operations and are thought to eventually discharge to the Berkeley Pit. The primary source of ground water in the Butte area is an alluvial unit that has been measured to be as thick as 640 feet. The alluvium is several hundred feet thick along the southern and eastern edges of the Berkely Pit and discharges several hundred gallons of water per minute to the pit. Material permeabilities for the alluvium are low (Hydrometrics 1983a).

Ground water along the Butte Metro Storm Drain varied in depth from one foot to 15 feet in a series of shallow wells drilled in 1983 by MBMG, (Duaime 1984). Forthcoming biannual MBMG data from these wells should provide valuable information on the quality of the alluvial ground water system in the vicinity of the Butte Metro Storm Drain.

Silver Bow Creek near the confluence of the Butte Metro Storm Drain and Blacktail Creek is a gaining stream. Ground water inflow is thought to be a primary source of increased total metals loading

evident in this area (Hydrometrics 1983d). The existence of tailings throughout this area is perhaps the source of the metals contamination. Many of the tailings deposits covered swampy areas and in turn have been covered by housing developments and parks, so their extent is not readily evident.

An oily substance seeps from the south bank of Silver Bow Creek just above the Colorado Tailings. Analysis of the seep has detected significant levels of oil and grease and PCP (Arrigo 1983). Potential sources of the oils and PCP are the Montana Pole and Treating Plant, LaVelle Powder Shop, and Montana Power Company Shop and the transformer yard.

The Montana Pole and Treating Plant (MP&T) apparently discharged oils containing PCP into Silver Bow Creek by means of a drainage ditch from about the time the plant opened in 1946 until perhaps as recently as 1982. Recent investigations by the Montana WQB and SWMB into ground water discharges from the area have led to the discovery of a large surface area affected by spills and a potentially large ground water area contaminated with oils and PCP (Arrigo 1983). Backhoe trenches dug on the site where spills had occurred showed oil staining in the upper two feet of soil, and brown, oily-smelling water at approximately 15 feet.

The Colorado Tailings have been studied in great detail. Duaime and others (1983) installed 2-inch diameter piezometers and 4-inch

diameter wells within the Colorado Tailings, alluvium underlying the Colorado Tailings, and nearby undisturbed alluvium. This investigation was a comprehensive analysis of ground water flow and chemistry throughout the tailings. The Colorado Tailings have commonly been thought of as the major source of total metals and sulfate loading to Silver Bow Creek. Recent investigations, however, raise some questions about the actual level of their impact. The primary source of impact is currently thought to be discharging ground water from the tailings. The primary area of ground water recharge to the tailings is the southeastern end. Discharge is along the western end (Hydrometrics 1983d). The water table is approximately two feet from ground surface with another apparently confined acquifer below the original ground surface. Due to the amount of existing data, no groundwater study of the Colorado Tailings is recommended.

3.1.3.2 Area II: Whiskey Gulch to Head of Canyon

Extensive floodplain tailings deposits are located on the floodplain of Silver Bow Creek in the vicinity of Ramsay, Silver Bow, and throughout most of the reach from Butte to the Warm Springs Ponds. Silver Bow Creek is a losing stream near the community of Silver Bow but gains flow near Miles Crossing. These conditions produce recharge and discharge areas respectively, for the tailings water table. The tailings at Silver Bow are typically above the water table, while the tailings at Ramsay contain a shallow water table and exhibit surface salt deposits. Ground water samples from the

Ramsay area show significantly poorer water quality than those from the Colorado Tailings (Hydrometrics 1983d).

The Stauffer Chemical Company phosphate plant is somewhat of an unknown entity in the evaluation of potential problem areas affecting Silver Bow Creek. In the past, effluent was discharged into a local storm drain, but there has been a contained process since 1972, except for cooling waters which were not recycled until 1975 (Pasichnyk 1984). Little is known about the plant's process water pond, except that it covers between 35 and 75 acres and is thought to be clay lined. There also appears to be a seepage ditch below it, but it is unknown if it ever contains water (Air Quality Bureau files).

Seven monitoring wells were installed during the 1950's at the Stauffer Chemical Company's Silver Bow Plant near Ramsay. Well construction data and recent (fourth quarter 1983) water quality data for five active monitoring wells were submitted to the MDHES-Water Quality Bureau for review (Shewman 1984). The value of obtaining specific hydrogeologic information from these wells is questionable. The wells are all relatively deep (225 feet to 303 feet) and are all perforated over total saturated thickness. Well number 6, for example, is perforated from 95 to 200 feet. Average flouride content for the fourth quarter of 1983 for this well was 3.78 parts per million (ppm). The large perforated interval of the well precludes an accurate determination of whether the high flouride is derived uniformly from the entire thickness of saturated sediments,

or in possibly even higher concentrations form a more limited stratigraphic interval.

Four monitoring wells were installed, pump tested, and sampled during 1982 by MBMG at the Butte-Silver Bow Metro Sewage sludge injection site, located just east of the Stauffer plant (Duaime 1983). These wells range in depth from 43 to 53 feet. Perforated intervals range from 13 feet to 15 feet. No significant degradation of shallow ground water quality was indicated by the sampling. Study recommendations, however, included continued periodic water quality monitoring and the installation of additional wells to better define site conditions.

3.1.3.3 Area IV: Warm Springs Ponds

The Warm Springs Ponds are situated on a floodplain where four streams come together to form the Clark Fork River. The material underlying is principally unconsolidated floodplain and outwash fan deposits, (Hydrometrics 1983g). Seepage from the Warm Springs Ponds apparently increases flow in the Mill-Willow Bypass by an average of 11 cfs, as well as significantly increasing sulfate and total metals loads (Hydrometrics 1983f).

3.1.3.4 Area V: Clark Fork River to Garrison

Ground water flow studies of the Deer Lodge Valley were conducted by Konizeski and others (1961, 1962, and 1968). More recent

analyses of ground water flow in the southern Deer Lodge Valley near the Anaconda Minerals Company ponds system has been completed by Hydrometrics (1981, 1983f). The Clark Fork River is a gaining stream between the Warm Springs Ponds and Deer Lodge (Konizeski and others 1961). Thin tailings deposits on the floodplain may be seasonally in contact with local ground waters; however, there does not appear to be any documentation of this.

3.1.4 Tailings and Water Quality

3.1.4.1 Contamination Mechanisms

Potential processes leading to metals contamination of ground and surface water by tailings are complex. A conceptual model of mechanisms for metals contamination from tailings in the Silver Bow Creek study area indicates five likely pathways. Processes which increase the solubility of metals can cause contamination of surface and ground water if the elements are present in abundance, and if the soil or soil solution is in contact with the water system. The five conceptual pathways are:

1. direct, physical erosion of tailings by stream action;
2. surface runoff from tailings introducing soluble salts to streams;
3. opportunities for direct chemical equilibria between tailings exposed to the channel and actual streamflow;
4. pyrite oxidation, leading to a low pH and increased metal solubility; or,
5. reduced redox potential due to a high tailings water

table, resulting in greater metal solubility.

Tailings materials can be directly entrained into the creek and constitute an unacceptable level of suspended sediment, while introducing substantial soluble metals to the creek. Runoff from the tailings and sediment during snowmelt or rainfall events can also carry a limited amount of dissolved salts from the top one to two centimeters of soil (Ahuja and Lehman 1983).

Runoff of precipitation from tailings and sediments probably occurs only infrequently in the study area due to high permeability of the sandy materials. Runoff likely occurs only during snowmelt events when subsoil layers are frozen, and during high intensity summer thunderstorms. The contribution of runoff to the total salt load in Silver Bow Creek is therefore expected to be low. Any correlation between rising stream stage and increased contact and direct chemical equilibrium of the stream with tailings and sediments, which is a third mechanism, appears to be unknown .

Another mechanism for heavy metal contamination is through alteration of the soil chemistry of tailings and waste deposits. Oxidation of pyrite in the sediment causes a low pH to develop, which in turn increases the solubility of a number of heavy metals. Percolation of precipitation or ground water then leaches the metals into the creek. To provide a preliminary evaluation of this process, a computer program was developed to estimate the amount of drainage

occurring from tailings in the Silver Bow Creek drainage. Results of the water budget simulation indicate that despite the area's dry climate, an average of 1.1 inches of water drain through the tailings and sediments each year. In a year with precipitation 30 percent above normal, 1.6 inches of drainage would occur. Although 1.1 to 1.6 inches of drainage does not seem excessive, with 300 or more acres of sediments, this amounts to 27.6 acre feet of contaminated water, or about 1,200,000 cubic feet per year. The fifth mechanism of contamination occurs when a high water table forms in the sediment. This slows the oxygen supply which leads to a "reduced" condition with the redox potential often falling below -100 mv (Bohn and others 1979). Although the pH of reduced soils is seldom below 6.5 (Ponnamperuma 1972), metal solubility is greatly increased (Stumm and Morgan 1981).

The importance of each mode of contamination is unknown, but the apparent contribution of metals to Silver Bow Creek is believed to result mostly from acid solubility, next from erosion and redox-induced solubility, and least from runoff. The amount of the total problem that is contributed by each of these modes should be evaluated prior to the development of site-specific remedial plans.

3.1.4.2 Observed Tailings Chemistry and Existing Data

Hydrometrics (1983e) conducted an inventory of the chemical and physical nature of tailings along Silver Bow Creek. The limited

data are the only available which evaluated extractable or soluble, rather than total elemental levels in the tailings. Total metal content is only weakly correlated with potential for leaching or plant uptake of an element. Further, even in acid materials, seldom more than five to ten percent of a metal is soluble (Maclean and Langille 1976).

A statistical summary of 39 tailings samples was conducted using data from Hydrometrics (Table 2-3, 1983e). Samples were collected from the Colorado Tailings and from four transects across the tailings at Rocker, Silver Bow, Miles Crossing and the Gregson Bridge.

The pH values were surprisingly uniform in the tailings materials, and were sufficiently low to produce average trace element levels (in a water extract) far in excess of maximum levels tolerated by plants. The products of pyrite oxidation, increased metal solubility, and partial breakdown of feldspars and other primary minerals in the acid environment resulted in a high salt content in many samples.

Although a number of reports have been prepared on the water quality of Silver Bow Creek, shallow ground water from Butte to Deer Lodge, and on the Warm Springs Ponds, there are very little data on the characteristics of tailings and waste materials. Hydrometrics (1983e) reported the only chemical and physical properties of tailings and waste found in the literature. Limited data on the location, thickness, and extent of tailings and waste were found in

the report by Hydrometrics, but the data presented do not allow investigators to calculate the amount of material in contact with the stream at various flood stages. There are few on-site data for use in remedial investigation or feasibility studies.

Efforts at data collection should identify the location of tailings and waste, and measure the thickness of all deposits. The presence of permanent or perched water tables should be determined, as should the proximity of wastes to the stream channel at different stages. Although Hydrometrics' (1983e) data can be used in this study, additional soil analyses should be collected from additional tailings and waste areas. Samples should also be collected from buried soil materials. Detailed soil pedon descriptions should be provided for each sample site. Acid production potential should be measured for all materials. Analysis of plant nutrient levels should be made of tailings and potential cover-soil to enable development of fertilizer and other treatment recommendations.

3.2 BIOLOGICAL

Biological systems associated with the Silver Bow Creek-Upper Clark Fork River have been subdivided into several components to facilitate discussion. These components are: 1) aquatic communities; 2) natural terrestrial communities; and 3) agricultural systems. The two terrestrial components (natural terrestrial communities and agricultural systems) were identified for separate discussion due to the unique nature of the problems associated with some of the agricultural systems.

3.2.1 Aquatic Communities

3.2.1.1 Fisheries Resources

The tributaries of Silver Bow Creek and Silver Bow Creek proper have not been systematically inventoried for their fisheries (MDFWP 1980; Holten 1983; Munther 1983; and Walsh 1983). However, Basin Creek is known to have at least a marginal fishery of brook trout (Salvelinus fontinalis) (Konizesk 1978) and Blacktail Creek probably contains some brook trout as well. Based on a review of available literature, it appears as though Silver Bow Creek from Butte to Warm Springs has no viable fishery. Tributaries to Silver Bow Creek in the vicinity of the Warm Springs Ponds, Willow Creek, and Mill Creek have moderate and substantial fisheries resources, respectively (MDFWP 1980). The Warm Springs Ponds and the Upper Clark Fork River both have viable fisheries, mostly brown trout

(Salmo trutla) (Hadley 1984). The Upper Clark Fork River from the Warm Springs Ponds to Bearmouth, west of Drummond, is classified as a high priority fishery resource (MDFWP 1980). However, in spite of this classification the fishery in the Upper Clark Fork River appears to have some problems due to contamination of the aquatic system. Phillips (1983) indicates that copper concentrations in winter and spring may be limiting fish productivity by depressing reproduction and affecting larval survivial of trout.

Past bioassay studies on the effluent from the Warm Springs Ponds concluded that "the biological data resulting from the egg and fry study indicated that exposure of the early life stages of rainbow trout to the five treatments did not have any adverse effects on egg hatchability and on survival and growth of fry through 60 days post-hatch" (EG&G 1978). The five treatments were tested during July 1 - October 21, 1977 and consisted of:

1. Warm Springs Pond #2 Effluent

2. Warm Springs Pond #2 Effluent enriched with cadmium at 20 µg/l (as CdO_2)

3. Warm Springs Pond #2 Effluent enriched with arsenic at 100 µg/l (as As_2O_3)

4. Warm Springs Pond #2 Effluent diluted with Warm Springs State Hatchery Water (at 1:3)

5. Clark Fork River Water from below the confluence of Warm Springs Pond discharge Mill-Willow bypass, and Warm Springs Creek.

The control waters for these tests were 100% Warm Springs State Hatchery water.

However, these tests were conducted when metal content of the pond #2 effluent was relatively low. A second bioassay study which repeated the first, but occurred during much higher levels of iron, copper, zinc, and manganese, concluded that the pond #2 effluent had a significant effect on weights of embryo and fry of rainbow trout (EG&G 1979). This study supports Phillips (1983) contention that trout populations maybe affected in the Upper Clark Fork River by "heavy" metal contamination.

The fisheries in the Upper Clark Fork River has also been investigated for metals residues in muscle tissue. Phillips (1982), Van Meter (1974), and Dent (1975) found that none of the fish muscle tissue tested had metal residues high enough to constitute a hazard to human health. The U.S. Food and Drug Administration action levels were used as the level of comparison for human health. Other conclusions of Phillip's (1982) study were:

- Mercury concentrations appeared to be higher in downstream samples than in samples from near the Warm Springs Ponds.

- Poor reproducibility of duplicate analyses for copper, cadmium and lead indicate there was a problem with sample matrix.

- If the intent of a study is to document metal exposure of a fish then the best tissues to analyze would be the liver and gill.

Several of the tributaries to the Upper Clark Fork River have been classified by MDFWP (1980). These are:

- Warm Springs Creek - Substantial Fishery Resource;
- Lost Creek - Moderate Fishery Resource;
- Dempsey Creek - Moderate Fishery Resource;
- Peterson Creek - Moderate Fishery Resource;
- Fred Burr Creek - Moderate Fishery Resource; and
- Little Blackfoot River - Sutstantial Fishery Resource.

The fisheries found within the study area vary from marginal in the headwaters, to non-existant from Butte to Warm Springs, to a good fishery with some problems in the Upper Clark Fork River.

Two fisheries studies are recommended; a trace metal study at the Warm Springs Ponds and a bioassay study on the Clark Fork River.

Trace Metal Study

A study of trace metal concentrations in fish tissues is recommended and is outlined in Section 2.0. The reasons for this recommendation are:

- The Warm Springs Ponds are open to fishing, and even though they are catch-and-release areas, there is a potential for occasional consumption of Warm Springs Ponds fish.

- Dent (1976) and Phillips (1982) found that brown trout in the Clark Fork River did not have dangerous concentrations of "heavy metals". However, they did not test fish directly from ponds. The study proposed would evaluate the health hazard of consuming fish from Warm Springs Ponds.

- Determination of contaminant concentrations in muscle tissue of fish residing in the Warm Springs Ponds will provide information that can be used to evaluate current operation and use of the ponds, assist in formulating proposals for alternating the existing operation of the ponds, and assist in evaluating proposals for new treatment facilities.

Bioassay Study

Past studies have indicated that "heavy metal" found in the Upper Clark Fork River may be affecting brown trout reproduction. A bioassay study is recommended to evaluate the affect upper Clark Fork River water has on trout reproduction. Justification include:

- The conditions of water contamination have changed since past bioassay studies as Anaconda Minerals Company no longer discharges NPDES permitted wastes from either the Butte Operations or the Anaconda Smelter.

- Documentation of the biological effects of the Silver Bow Creek contamination that has not been treated by the Warm Springs Ponds would provide needed information for defining the extent and severity of the existing problems. Salmonid fish such as brown trout are sensitive to water contamination and are good indicator species.

- The brown trout fishery of the Upper Clark Fork River has a significant local economic value and an enhancement of this fishery could contribute to the local economy.

The Remedial Action Master Plan (CH_2M Hill 1983) and the EPA-MDHES Cooperative Agreement (SWMB/MDHES 1983) both recommended bioassay studies of the brown trout fishery in the Upper Clark Fork River.

Both reports listed five sites for evaluating effects that heavy metals may have on brown trout. These five sites included the following:

1. Silver Bow Creek upstream from the Warm Springs Ponds;
2. Silver Bow Creek between Warm Springs Pond and Warm Springs Creek;
3. Warm Springs Creek;
4. The Clark Fork River; and
5. The confluence of Warm Springs Creek with Silver Bow Creek.

Sites one through four were designated for instream incubation of eggs and larval fish and site five as a chronic flow-through site. However, only a single chronic flow through test at site four is recommended. This instream test of eggs and larval fish would provide numbers of organisms that successfully hatch and survive utilizing Clark Fork River water.

An additional study is recommended and is described in Section 2.0 of this document to determine if gametes of adult brown trout in the Clark Fork River are viable. This study is recommended as it will provide data on brown trout reproduction that cannot be obtained from bioassay studies alone.

3.2.1.2 Invertebrates

There is no written record of the biological conditions of Silver Bow Creek prior to the commencement of silver mining in Summit Valley in the 1860's. From that date until 1972 when the Anaconda Minerals Company began recycling its waste waters from its mining and smelting operations, it was described as a "biological desert" by Dr. George Wiesel of the University of Montana (Wiesel 1972).

No benthic organisms were reported by the EPA or by the Montana College of Mineral Science and Technology in 1972 and 1973 (Fox 1972; Gless 1973). Gless (1973) reported a good or acceptable diversity index in Blacktail Creek and Yankee Doodle Creek above the Berkeley Pit sludge ponds; both feeder tributaries to Silver Bow Creek. There have been no reports since that time to alter the data.

However, Harner-White Ecological Consultants, Inc. (1982), reporting to the Anaconda Minerals Company indicated Diptera downstrean of the Montana Street bridge and upstream of Rocker, Montana (Stations 1 and 2). Trichoptera were also found at Miles Crossing downstream of Ramsay (Station 3) and in large numbers at Gregson Bridge near Gregson Hot Springs. This station is at Highway 10A on Silver Bow Creek and is not near Gregson Creek or Fairmont Hot Springs.

Mayflies were found at all Silver Bow Creek Stations except Stewart Street Bridge (Station 5) in 1982 (Chadwick and Associates 1983). A synopsis of both Harner-White and Chadwick and Associates data is presented in Table 3-1, Benthic Insects Collected from Silver Bow Creek.

Trichoptera were also found in large numbers upstream of Stewart Street Bridge east of Opportunity, Montana (Station 5). No Mayflies and only one Stonefly (at Station 4) were found in the Harner-White study. The density and number of species both increased drastically from Station 1 to Station 5 and Harner-White wrote "....the fact that any invertebrates were collected is significant and may point to the beginning of recovery in upper Silver Bow Creek."

Chadwick and Associates (1983) reporting to the Anaconda Minerals Company, comment that:

> ".....mining and municipal wastes ..... had a devasting effect on the invertebrate community, which is only now beginning to recover; ten years after initiation of mining waste water treatment at Butte. Invertebrate populations in Silver Bow Creek have fluctuated greatly with truly resident communities just becomming established at the upper stations in 1982. Although densities were much higher in 1982, the results are still indicative of a stressed community."

TABLE 3-1.--BENTHIC INSECTS COLLECTED FROM SILVER BOW CREEK
(Stations and years as indicated, taken from Harner-White Ecological Consultants, Inc., Report, 1982 and Chadwick and Associates, Report, 1983.)

Station	Taxa	COLLECTION YEARS 1975	1976	1978	1979	1980	1981	1982
1	Ephemeroptera							11
	Plecoptera	--	--	--	--	--	--	--
	Trichoptera	--	--	--	--	--	--	40
	Diptera	--	--	--	--	--	58	1982
	Coleoptera	--	--	--	--	--	--	--
2	Ephemeroptera							7
	Plecoptera	--	--	--	--	--	--	--
	Trichoptera	--	--	--	--	--	--	--
	Diptera	--	--	--	--	--	59	1853
	Coleoptera	--	--	--	--	--	--	4
3	Ephemeroptera							7
	Plecoptera	--	--	--	--	--	--	--
	Trichoptera	--	--	--	--	--	86	28
	Diptera	--	81	--	--	--	1468	2587
	Coleoptera	--	--	--	--	--	--	14
4	Ephemeroptera							22
	Plecoptera	P*	P	--	--	4	4	4
	Trichoptera	P	27	P	115	4	238	2661
	Diptera	P	86	P	86	402	695	2019
	Coleoptera	--	--	--	--	--	19	18
5	Ephemeroptera							--
	Plecoptera	--	--		--	--	--	4
	Trichoptera	--	--		1371	36	8515	1311
	Diptera	P	59		1091	1039	2455	747
	Coleoptera	P	--		--	7	50	7

* The text of these papers did not explain the significance of "P" except to comment that it equaled "present".

A 1983 study has been completed but was not available for review prior to drafting of this report (Windorski 1984).

Available data indicate an almost complete recovery of invertebrates below the Warm Springs Ponds after the Anaconda Mineral Company's Butte Operations initiation of their waste water treatment program. While benthic invertebrate densities and diversities have improved below the ponds, it is not likely that they will ever be as high as the Lower Clark Fork River. This is probably because of Butte Municipal sewage water enrichment (Chadwick and Associates 1983).

No benthic invertebrate data was found for the Warm Springs Ponds.

The first attempt to sample Silver Bow Creek in recent years was probably by Spindler (1957). A Surber square foot sampler was used with no indicated attempt to riffle selection. Since that time much improvement in sampling techniques and analysis has been made. The Surber Sampling collection method was vastly improved upon with the development of the Circular Waters-Knapp sampler which encloses 0.09 M^2 (1 ft^2), as reportedly used by Harner-White (1982) and Chadwick and Associates (1983). While Spindler (1957) made no attempt to place a numerical index upon the numbers of taxa collected, the previous two authors did. The Shannon-Weiner Index (Weber 1973) is probably the best index for the type of benthic invertebrates and the stream bottoms found in Silver Bow Creek. The existing data from such a badly damaged, impacted, and recovering stream such as Silver Bow Creek is probably the best and least expensive

that could have been obtained by using these methods. These data are adequate for remedial investigation goals.

A "paper study" compilation of existing information on the macroinvertebrates of Silver Bow Creek and the Upper Clark Fork River is recommended. A report of this nature will expedite the feasibility studies and endangerment assessments.

3.2.1.3 Algae

Four studies of algae in the Upper Clark Fork River system have been researched. William T. Barry (1956) studied the algae at 13 stations between Butte and Missoula. Barry reported that Asterionella gracillima, Dinobryon divergens, and Ulothrix zonata showed a tolerrance to a wide range of chemical and physical factors. Numbers of species found at stations above pollutant sources decreased abruptly at stations below. The few tolerant species found below pollution inputs were much more abundant than those at the station above. Euglena gracilis was found at the polluted sites of Gregson and Warm Springs. This species was more abundant at the more heavily polluted Gregson than at Warm Springs. Stigeoclonium subsecundum was found at Warm Springs and at other stations downstream. It was not found upstream of sewage inputs into the system.

Janik and Melacon (1982) made one algae collection in August 1980 at five stations, three above the Warm Springs Ponds on Silver Bow

Creek and two below the ponds. Navicula arveusis was the dominant diatom species contributing over 90% relative abundance at each of the three upstream stations. A chrysophyte, Phaeodermatium rivulare, was the dominant non-diatom species at two upstream stations and a green alga, Stigeoclonium tenue was the dominant non-diatom at the other. This zone was characterized by high levels of arsenic, cadmium, chromium, copper, selenium, and zinc. Mean diatom diversity (Shannon-Wiener index) for the three stations was .53. Euglenoids were observed in low abundance.

Diatom species diversity increased and species composition changed in the two stations below the Warm Springs Ponds in the Clark Fork River. The dominant diatom species were Achnanthes minutissima, Nitzschia palea, Fragilaria vaucheriae, and Gomphonema parvulum. Navicula arvensis was present in much lower abundance than above the ponds. The non-diatom species were dominated by the blue-green species Phormidium sp. and Lyngbya aerugineocarulea. A one-way analysis of variance demonstrated that diatom diversity was statistically signficantly higher in the stations below the ponds than above. Mean diversity at the two downstream stations was 2.11. Diatom species that indicated tolerance for the existing conditions, both upstream and downstream were: Cyclotella memeghiniana, Achnanthes minutissima, Navicula arvensis, Nitzschia palea, Surirella angustata, and Surirella ovata. Species indicating sensitivity to conditions in the upstream stations but not in the downstream stations were: Fragilaria vaucheriae, F. Crotonenis var. oregona,

F. leptostauron var. dubia, and Navicula pupula. Melosira varians was the only species occurring in each of the upstream stations but was absent from the downstream stations.

Bahls (1983) reported an algae collection from four sites in Silver Bow Creek in April 1983. Collections were made above the Colorado Tailings and the Butte Waste Water Treatment Plant, at Rocker below the Colorado Tailings and the Butte Waste Water Treatment Plant, at Miles Crossing below Ramsay, and at Gregson below German Gulch.

Diatoms dominated the aquatic flora above the Colorado Tailings and the Butte Waste Water Treatment Plant but blue-green algae dominated the collection at the downstream stations. The blue-green species were non-descript, micron sized, coccoid types. Green algae (mostly Stigeoclonium) was represented by a progressively larger ration of the flora in a downstream direction. Achananthes minutissima was the principal diatom species above the tailings and Navicula atomus was the principal species downstream. Diversity of diatom taxa (Shannon index) was low varying between .43 to 1.33.

Silver Bow Creek below Warm Springs Ponds and the Clark Fork River at Deer Lodge were sites of algae collections in August and November 1977 and March 1978 by the DHES Biological Water Quality Monitoring Program. Water chemistry measurements, as well as algal community measurements, were made.

The results of the study indicate that Silver Bow Creek receives nitrogen and phosphorus levels significantly in excess of recommended instream concentrations. The addition of organic material to the stream may enhance the removal of metal species by the formation of organic-metal complexes and by the enhancement of algae growth, (Bahls 1983). Algae has been shown to be an effective accumulator of metals. Therefore, it seems that the fate of organic waste water treatment is very important to the metal pollution problem. Diatoms dominated the flora in Silver Bow Creek during the summer and spring. A green alga, Cladophora, was most abundant in the fall. The Clark Fork River site reflected the same dominance.

The major diatom species in Silver Bow Creek was Achnanthes minutissima in all three seasons. Nitzschia palea, Gonphonema parvulum, Synedra ulna, and Fragilaria vaucheria had high relative abundance also. The Clark Fork River samples were dominated by Achananthes minutissima in the summer and spring and F. vaucheria in the fall. Nitzschia palea, and Navicula minima were other species with high abundance.

Diversity index values for the diatom community ranged from 2.48 to 3.58 in the Silver Bow Creek station and 2.89 to 3.04 at the Clark Fork station.

The existing conditions in the Silver Bow/Clark Fork system shows severe pollution related stress in Silver Bow Creek and incomplete recovery in the Clark Fork River.

Very little information is available on the algal populations of Silver Bow Creek and the Warm Springs Settling Ponds or the roles that they might play in heavy metal movement. Algae are present and may provide a third removal mechanism along with sedimentation and precipitation.

Also, they may be strongly involved with metal mobilization by release upon decomposition and pH depression during (metabolic) respiration.

Only preliminary information is available on the algal populations of the Ponds. A late season (October 15) collection by duRuiter (1984) gave the following information:

Pond Number	Algae Genera
3	Mainly Cladophora Some Oscillatoria Diatoms (mainly Navicula, Fragilaria)
2	Mainly Cladophora Some Oscillatoria, Ulothrix, Diatoms (Navicula, and Fragilaria)
1	Mainly Cladophora Some Spirogyra, Diatoms (Navicula, and Fragilaria)

This data is in agreement with upstream information (Bahls 1983) where blue-green algae dominate, but diatoms are present. Since

most algae characteristics are species-specific, further algal collections and identification to species are recommended.

When the Ponds are fully operational, algae may be an important metals removal or transport mechanism. Jennett et al. (1983) observed that young cultures were very effective in removing metals, and concentration factors of $> 1 \times 10^4$ were observed. Neutral and basic pHs are typically the most effective and this condition would be met during liming of the Ponds. Surface absorption appears to be the mechanism of dissolved metals removal by algae, while re-mobilization of the metals may occur during algal decay (deRuiter 1984). Efficient dissolved metals removed by algae therefore require three steps:

1. Absorption on algae;
2. Retention of algae in ponds; and
3. Retention of metals in the algae or sediments.

Algae may also absorb metals from the sediments (Laube et al. 1980, 1979). Preliminary work by duRuiter (1984) on the Ponds produced the following benthic algal metals data:

Pond Number	Metal	Concentrations (ppm)
3	Copper	1877
	Cadmium	50
	Arsenic	85.6
2	Copper	316
	Cadmium	16.8
	Arsenic	59.2

Pond Number	Metal	Concentrations (ppm)
1	Copper	171
	Cadmium	2.32
	Arsenic	51.6

The results are expected to correlate better with sediment metals levels than water column metals levels. Upon decay of the algae, metals may be released to the water column and exit from the Ponds. During active operation, algae were probably a major contributor to the removal of dissolved metals and added to the effectiveness of the Ponds as a means of removing metals. Currently, algae may be mobilizing sediment-bound metals thus contributing to dissolved metals exiting the Ponds. Further study is recommended to assess the role that algae play in the Ponds so that metals removal might be enhanced and mobilization retarded.

A program with the following general guidelines is recommendd.

1. Sample and identify algae (to species);
2. Sample and determine water column metals (total and dissolver);
3. Sample and determine sediment metals; and
4. Sample and determine algal metals (total and absorbed).

Periodic samplings may be required to assess growth, stagnation, and decay conditions. Also, nutrient and species specific algal bio-assays may be necessary to determine optimum conditions. This

latter data would help in the design of an algal meander system. These bioassays are not recommended for immediate performance, but may be appropriate following an analysis of the results of the proposed algal investigation.

3.2.2 Natural Terrestrial Communities

This discussion of the current conditions of the natural terrestrial biological communities associated with Silver Bow Creek and the Upper Clark Fork River has been divided into floral and faunal components for discussion. Within each of these components, the discussion follows a geographic pattern from upstream to downstream on the Silver Bow Creek-Clark Fork River system.

3.2.2.1 Floral Communities

Natural plant communities found within the floodplain area of Silver Bow Creek and the Upper Clark Fork River are the only plant communities that are potentially impacted by Silver Bow Creek contamination. For this reason, this discussion is limited to the floodplain area within the study area boundaries.

Floodplain vegetation of the tributary streams has not been studied in depth. Ross and Hunter (1976) describe the climax range site for the Summit Valley as a silty range site with 15-19 inches of precipitation. This range site is characterized by rough fescue

(Festuca scabrella), needlegrass (both Stipa comata and Stipa richardsonii), and basin wildrye (Elymus cinereus). However, these species are characteristic of upland sites and probably do not represent the topo-edaphic climax found within the floodplain of Blacktail Creek and Basin Creek within the Summit Valley.

A casual inspection of the floodplain vegetation associated with these two tributary streams of Silver Bow Creek reveals that major overstory species include cottonwood (Populus spp.) willow (Salix spp.), and alder (Alnus spp.). Other species occuring include reedgrass (Calamagrostis spp.), magina grass (Glyceria spp.), and tall wheatgrass (Agropyron elongatum) with rush (Juncus ssp.) and cattails (Typha latifolia) found where the water table is at or above the ground surface. The plant communities associates with these two major tributary streams have not been affected by major industrial activity, however, the vegetation growing in the floodplains has been altered by man's activities, primarily suburban and urban development, and agriculture. They do not represent pristine conditions, but are representative of the possible beneficial uses of plant communities found in local healthy floodplains.

Plant communities of the Silver Bow Creek floodplain from Butte to the Warm Springs Ponds have been extensively affected by past industrial activity. A casual inspection of the floodplain indicates that the major impact to plant communities has been caused by deposition of mine and mill tailings and wastes, covering the

original floodplain. Many of these areas are devoid of plant life, or if it exists, it is a sparse, weedy community.

The vegetation of the Silver Bow Creek floodplain to the Warm Springs Ponds has not been studied intensively. Ross and Hunter (1976) describe the climax vegetation in this section of the study area as that found in limely-shallow sites, silty range sites, and saline lowland range sites. Vegetation found associated with limey-shallow sites includes Bluebunch wheatgrass (Agropyron spicatum), prairie junegrass (Koeleria cristata, and needle and threadgrass (Stipa comata). These are upland species so probably do not represent the species composition of the Silver Bow Creek floodplain from Butte to the mouth of the Silver Bow Creek Canyon. The silty range site, described above, probably represents the vegetation found near the creek as it passes through the Silver Bow Creek Canyon; there is no well developed floodplain through this area. The saline lowland range site, characterized by basin wildrye (Elymus cinereus), Alkali sacaton (Sporobolus airoides), and Nuttall alkaligrass (Pucinella nuttalliana), (Ross and Hunter 1976), appears to occur on the Silver Bow Creek-Upper Clark Fork River floodplain down stream of the Canyon.

Hydrometrics (1983e) performed a reconnaissance-level vegetation survey along Silver Bow Creek in 1982. Their findings are presented in Table 3-2, Tailings Area Vegetation Along Silver Bow Creek. Hydrometrics (1983e) found that where the tailings had eroded away

TABLE 3-2.--SILVER BOW CREEK AREA VEGETATION[a,b]

Common Name	Scientific Name	Near Rocker SB01[c]	Near Silver Bow SB02[c]	Near Miles Crossing SB03[c]	Near Gregson Bridge SB04[c]
Western Wheatgrass	Agropyron smithii		X		
Bentgrass	Agrostis spp.			X	X
Colonial Bentgrass	Agrostis tenuis		X		
American Sloughgrass	Beckmannis syzigachne		X		
Sedge	Carex spp.			X	X
Sedge	Carex lenticularis	X	X		
Tufted Hairgrass	Deschampsia caespitosa	X	X	X	X
Inland Saltgrass	Distichlis stricta		X		X
Wildrye	Elymus spp.		X		
Rush	Juncus spp.	X	X	X	X
Bluegrass	Poa spp.				X
Bulrush	Scirpus microcarpus		X		
Cattail	Typha latifolia		X	X	X

[a] Source: Hydrometrics 1983.
[b] Most species occrued at the margin's of the tailings areas.
[c] These numbers refer to Hydrometrics' sampling sites.

TABLE 3-2.--SILVER BOW CREEK AREA VEGETATION[a,b]

Common Name	Scientific Name	Near Rocker SB01[c]	Near Silver Bow SB02[c]	Near Miles Crossing SB03[c]	Near Gregson Bridge SB04[c]
Wild Onion	Allium spp.				X
Canada Thistle	Cirsium arvense			X	
Common Horsetail	Equisetum arvense	X			
Leafy Spurge	Euphorbia esula			X	
Sorrel	Rumex spp.		X		
Common Salsify	Tragopogon dubius			X	
Thinleaf Alder	Alnus incana	X			
Rose	Rosa spp.	X			
Willow	Salix spp.	X	X		
Firmleaf Willow	Salix myrtillifolia				X

a Source: Hydrometrics 1983.
b Most species occrued at the margin's of the tailings areas.
c These numbers refer to Hydrometrics' sampling sites.

to the original soil that willows (Salix spp.) and several grasses such as Tuffed hairgrass (Deschampsia caespitosa) and bentgrass (Agrostis spp.) have recolonized. They also found that inland saltgrass (Distichlis stricta) and the scorpion plant (Phacelia hastata) were colonizing some tailings areas. Generally, they found the tailings areas in the floodplain from Butte to Warm Springs to be devoid of vegetation (Hydrometrics 1983e).

Hydrometrics (1983f) also performed a reconnaissance-level vegetation survey of the Warm Springs Ponds area. Plant species were identified at each soil sampling site. The results of this survey are reproduced in Table 3-3, Warm Springs Ponds Area Vegetation. The Hydrometrics (1983f) survey missed several species that occur in the pond area; these include cottonwoods (Populus spp.), yellow willow (Salix rigida), and white willow (Salix alba). A thorough field survey would reveal many more species.

The Clark Fork River floodplain vegetation below the Warm Springs Ponds has not been affected as much as Silver Bow Creek by tailings deposits. According to Ross and Hunter (1976), the climax plant community for the Clark Fork floodplain from Warm Springs to the confluence with the Little Blackfoot River alternates between a saline lowland range site and a silty range site with 10-14 inches precipitation. A saline lowland range site is characterized by basin wildrye (Elymus cinereus), alkali sacaton (Sprorbolus airoides), Nuttall alkaligrass (Puccinellia nuttalliana), western wheatgrass

TABLE 3-3.--WARM SPRINGS POND AREA VEGETATION[a]

Common Name	Scientific Name	SWP2-1[b]	WSP3-1[b]	WSP3-2[b]
Wheatgrass	Agropyron caninum	0		
Crested Wheatgrass	Agropyron cristatum	X		
Western Wheatgrass	Agropyron smithii			X
Bentgrass	Agrostis spp.		X	X
Colonial Bentgrass	Agrostis tenuis	0		X
Smooth Brome Grass	Bromus inermis	0		
Tufted Hairgrass	Deschampsia caespitosa	0	0	
Inland Saltgrass	Distichlis stricta		0	X
Idaho Fescue	Festuca idahoensis			X
Foxtail Barley	Hordeum jubatum	0		
Rush	Juncus spp.	0		X
Alkali Cordgrass	Spartina gracilis			X
Alkali Sacaton	Sporobolus airoiles			X
Cattail	Typha latifolia	0		

[a] Source: Hydrometrics 1983.
[b] These numbers refer to Hydrometrics' sampling sites.
X = Present at site.
0 = Present in vicinity of site.

TABLE 3-3.--WARM SPRINGS POND AREA VEGETATION[a] (Continued)

Common Name	Scientific Name	SWP2-1[b]	WSP3-1[b]	WSP3-2[b]
Aster	Aster campestris	0		
Whitetop	Cardaria draba	0		X
Spotted Knapweed	Centaurea maculosa	0		
Horsetail	Equisetum spp.		0	X
Butter and Eggs Toadflax	Linaria vulgaris	0		
Hoary Asta	Machaerauthera canascens (a.k.a. Aster canascens)	0		
Alfalfa	Medicargo sativa	0		
Yellow Sweet Clover	Melilotus officianalis	0		
Plantain	Plantago spp.			X
Goldenrod	Solidago spp.			X
Shore Arrowgrass	Triglochin maritimum			X

a Source: Hydrometrics 1983
b These numbers refer to Hydrometrics' sampling sites.
X = Present at site.
0 = Present in vicinity of site.

TABLE 3-3.--WARM SPRINGS POND AREA VEGETATION[a] (Continued)

Common Name	Scientific Name	SWP2-1[b]	WSP3-1[b]	WSP3-2[b]
Aster	Aster campestris	0		
Whitetop	Cardaria draba	0		X
Spotted Knapweed	Centaurea maculosa	0		
Horsetail	Equisetum spp.		0	X
Butter and Eggs Toadflax	Linaria vulgaris	0		
Hoary Asta	Machaerauthera canascens (a.k.a. Aster canascens)	0		
Alfalfa	Medicargo sativa	0		
Yellow Sweet Clover	Melilotus officianalis	0		
Plantain	Plantago spp.			X
Goldenrod	Solidago spp.			X
Shore Arrowgrass	Triglochin maritimum			X

a Source: Hydrometrics 1983
b These numbers refer to Hydrometrics' sampling sites.
X = Present at site.
0 = Present in vicinity of site.

(Agropyron smithii), thickspike wheatgrass (Agropyron dasystachyum), inland saltgrass (Distictlis stricta), Nuttall saltbush (Atriplex nuttallii), and greasewood (Sarcobatus vermiculatus), (Ross and Hunter 1976).

Hydrometrics (1983g) performed a reconnaissance survey of the vegetation found at its soil sampling sites (Table 3-4, Clark Fork River Area Vegetation). These species represent a combination of early colonizers and high water table species.

Recommended Study

It is recommended that the floodplain vegetation of Blacktail Creek, Basin Creek, and Silver Bow Creek to Whiskey Gulch be mapped at the largest available scale, and that each mapping unit's vegetation be described qualitatively. The reasons for this recommendation are:

- Knowing the general make-up and areal extent of vegetation communities found along the relatively undisturbed tributary streams will enable an investigator to evaluate the disturbed portions of the Silver Bow Creek floodplain. The area of riparian habitat and the probable vegetation communities that make up these areas can then be estimated.

- Knowing the make-up and areal extent of vegetation communities along the disturbed portion of Silver Bow Creek will

enable an investigator to perform the task described above. Furthermore, as one of the mapping units will be the tailings/disturbed areas, an investigator will be able to describe those plant species and plant assemblages that are tolerant of conditions found in the disturbed areas.

- Knowing those plant species and plant assemblages that are tolerant to disturbed area conditions will enable an investigator to recommend appropriate species for use in revegetation reclamation efforts.

- Knowing the locations and areal extent of floodplain plant communities will enable an investigator to identify potential reclamation sites, borrow sites, and sources of reclamation materials.

- Knowing the location and areal extent of floodplain plant communities will also help hydrogeologic investigators, as plant communities are often indicative of groundwater conditions.

3.2.2.2 Faunal Communities

The faunal communities occurring in the Summit Valley are common within the Northern Rocky Mountains. Once out of the urban and suburban areas of the Valley wild animals are frequently encountered.

TABLE 3-4.--CLARK FORK RIVER AREA VEGETATION[a]

Common Name	Scientific Name	CLFK 3	CLFK 100 A & B
Sweetvetch	Hedysarum spp.		X
Sunflower	Helianthus spp.	X	
Rocky Mountain Iris	Iris missouriensis		X
White Sweetclover	Melilotus officinalis	X	
Mint	Mentha spp.		X
Mexican Dock	Rumex salicifolius var. triangularis	X	
Goldenrod	Solidago missouriensis	X	
Sowthistle	Souchus uliginosus	X	
Clover	Trifolium spp.	X	X
Thinleaf Alder	Alnus incana	X	X
Wedgescale saltbrush	Atriplex truncata		X
Shrubby cinquifoil	Potentilla fruticosa	X	
Rose	Rosa spp.		X
Willow	Salix spp.	X	X
Slender Willow	Salix exiqua	X	X
Common Snowberry	Symphoricarpos albus		X
Redtop Bentgrass	Agrostic alba	X	X
Tufted Hairgrass	Deschampsia caespitosa	X	X
Inland Saltgrass	Distichlis stricta	X	X
Spike Sedge	Eleocharis palustris		X
Foxtail Barley	Hordeum jubatum		X
Wire Rush	Juncus balticus		X

[a] Source: Hydrometrics 1983.

TABLE 3-4.--CLARK FORK RIVER AREA VEGETATION[a] (Continued)

Common Name	Scientific Name	CLFK 3	CLFK 100 A & B
Alkali Muhly	Muhlenbergia asperifolia		X
Beinnial Sagewort	Artemesia biennis	X	
N.A. (Booth and Wright 1966)	Aster falcatus	X	X
Smooth Aster	Aster laevis	X	X
Littlepod Falseflax	Camelina microcarpa	X	X
Spotted Knapweed	Centaurea machulosa		X
Field Chickweed	Cerastium arvense		X
Lamb's Quarter	Chenopodium album		X
Glandular Willow-Herb	Epilobium glandulosum	X	
Common Horsetail	Equisetum arvense	X	
Golden Weed	Haplopappus integrifolius	X	X

[a] Source: Hydrometrics 1983.

However, as the main area of concern for the Silver Bow Creek "Superfund" site lies within the floodplain, only those animals that occur there are considered in the following discussion.

The major wildlife resource associated with the floodplains of Blacktail Creek and Basin Creek is waterfowl. Both streams are used by waterfowl in the Spring and Fall during migration, and several valley areas are potentially used for nesting and brood rearing. The major potential areas used for nesting include a marshy area at the confluence of Blacktail Creek and Basin Creek, and a small reservoir located on an ephemeral tributary to Blacktail Creek.

Other wild animals such as mice and songbirds utilize the floodplain but are not as affected by water quality as waterfowl.

There is no apparent wildlife use of Silver Bow Creek from the Weed Concentrator to the confluence with Blacktail Creek as this part of the creek bed has been channelized and the area is urban in nature. From the confluence with Blacktail Creek to the Warm Springs Ponds, Silver Bow Creek supports occasional use by waterfowl during the Spring, Summer, and Fall. However, the intensity of this use has never been documented. Other floodplain wild animals utilizing the creeks in this section may include deer and elk (in the canyon section of the creek), songbirds, small mammals, and upland game birds.

The Warm Springs Ponds are leased by the Montana Department of Fish, Wildlife, and Parks from Anaconda Minerals Company and are managed as a Wildlife Management Area (WMA) (Greene 1984b). Major emphasis of management for this area is waterfowl habitat enhancement (Greene 1984b). Waterfowl use of the area during the Spring, Summer, and Fall is heavy, with some birds overwintering (Greene 1984b). No records have been maintained, but Greene (1984b) indicates that waterfowl use and production have increased within the last ten years.

The area is attractive to waterfowl due to its relatively shallow water, adequate macrophytes, adequate fish populations (for fish eating waterfowl), minor disturbance potential, and efforts by MDFWP to enhance waterfowl habitat through small grain plantings, having a portion of the area closed to hunting, and creation of nesting habitat through island construction.

Diving ducks and puddleducks utilize the ponds. Species observed there include: conada goose (Branta canadensis), snow goose, (Chen hyperborea), mallard (Anas platyrhynchos), pintail (Anas acuta), gadwall (Anas strebera), green-winged teal (Anas carolineusis), blue-winged teal (Anas discors), cinimmon teal (Anas cyanoptera), American widgeon (Mareco americana), shoveler (Spatula clypeata), wood duck (Aix sponsa-in the vicinity), Red head (Aythya americana) ring-hecked duck (Aythya collaris), canvasback (Aythya valisineria), Scaup (Aythya marila, and A affinis), Common Goldeneye (Bucephala

clangula), Barrows Goldeneye (Brucephalia islandica), Bufflehead (Brucephala albeola), ruddy duck (Oxyura jamaicensis), hooded merganser (Lophodytes cucullatus), common merganser (Mergus merganser), red-breasted merganser (Mergus serrator), common loon (Gavia immer), Red-necked grebe (Podiceps grisegena), horned grebe (Podiceps auritus), eared grebe (Podiceps nigricollis), western grebe (Aechmophorus occidentallis), and the pied-billed grebe (Podilymbus podiceps) (Trout 1983; Stoecker 1984; Skarr 1980). Other shorebirds such as sandpipers, coots, avocets, and cranes utilize this area (Trout 1983; Stoecker 1984; Skarr 1980).

The only "heavy metal" work to date on waterfowl from the Warm Springs Ponds was in 1971. Results from this investigation, along with data from tissue analysis from ducks taken at different places or times in Montana, are shown in Table 3-5. The data shown in Table 3-5 are not sufficient to determine: 1) whether or not these levels are elevated above background due to the ducks accumulating these levels from their habitat, or 2) whether or not these levels would indicate a health hazard to humans consuming the ducks (metals tend to accumulate in kidney and liver tissue, not muscle tissue) (USEPA 1981).

Shambaugh (1983) studied the trace metal accumulation within the food chain at the Warm Springs Ponds. He determined that his data was insufficient for conclusions but that it indicated the possibility of bioaccumulation by the aquatic biota inhabiting the ponds

(Shambaugh 1983). If bioaccumulation is occurring in the aquatic biota, then waterfowl utilizing this biota for food may be exposed to elevated levels of "heavy metals."

Neher and Weisel (1977) examined the effects of heavy metal accumulation and its effects on the biota of Warm Springs Ponds. However, they did not examine waterfowl tissue.

The major wildlife group occurring within the floodplain of the Clark Fork River that is potentially affected by contamination of the river is waterfowl. Waterfowl use the Upper Coark Fork River year-round, with major migration peaks occurring in the Fall and early Spring (Greene 1984b). Production of ducks and geese occurrs in this section of river, but no records are available (Greene 1984b). No tissue analysis of ducks from this area have been performed (Greene 1984b). Species occurrence here is probably similar to that found on the Warm Springs Ponds.

The Montana Department of Fish, Wildlife, and Parks are currently developing some additional waterfowl production ponds north of existing Warm Springs Ponds. These ponds are being constructed from gravel pits excavated for interstate highway construction in the area. Fill water from these ponds will come from surface water run-off and ground water (Greene 1984b). These ponds should be ready to fill by the end of 1984. These ponds will add new waterfowl habitat to the Warm Springs/Clark Fork River area, which will

TABLE 3-5.--TRACE METAL LEVELS IN DUCK TISSUE

Species	Location	Kidney ppm			Liver ppm			
		Cd	Pb	Zn	As	Cd	Pb	Zn
Mallard	Warm Springs Ponds[1]				0	1.7	10-16	50
Mallard	Warm Springs Ponds[1]				0	12	10-16	110
Mallard	Great Falls[1]				0	.44	16-24	320
Mallard	Great Falls[1]				0	.44	16-24	70
Mallard A	Giant Springs[2]	1.08	4.3	117		.50	10.9	376
Mallard 1	Giant Springs[2]	1.72	6.9	147		.36	21.1	306
Mallard 2	Giant Springs[2]	.44	5.7	153		.10	26	301
Mallard 3	Giant Springs[2]	4.1	26.9	125		.24	22.0	124
Mallard 4	Giant Springs[2]	8.5	20.5	136		.74	15.1	288
Mallard	Unknown Control[2]	.42	0	19.8		.14	0	72.8

[1] Source: Hooper 1971.

[2] Source: Champa 1965.

contribute to the overall attractiveness of the area to both waterfowl and waterfowl hunters.

Only one threatened or endangered species occurrs within the study area. The Northern Bald Eagle (Haliaeetus leucocephalus) has been observed utilizing the Warm Springs Pond Area (Stoecker 1984). They are probably drawn to the area by the Fall, Winter, and Spring concentrations of waterfowl (Griffin, et al. 1982). No nesting in the area has been observed. Probable food sources for the eagles utilizing the area includes waterfowl (Griffin, et al. 1982) and fish (Steenhof 1978).

Recommended Studies

A wildlife study is recommended for the Warm Springs Ponds area as part of the Remedial Investigation. This study will: 1) determine the concentrations of Silver Bow Creek contaminants in waterfowl muscle, and 2) evaluate the human health hazard of consuming waterfowl utilizing the Warm Springs Ponds.

The reasons for performing this study are:

- Knowledge of contaminant concentrations in waterfowl tissue will aid in determining the extent and severity of contamination from Silver Bow Creek.

- Existing data is not sufficient to determine whether or not waterfowl utilizing the ponds, either year-round or seasonally are picking up higher than normal concentrations of contaminants.

- Existing data is insufficient to evaluate the health hazard to humans from consuming waterfowl utilizing the ponds.

- Knowledge of contamination of waterfowl and its effects, either to humans consuming the waterfowl, or to the waterfowl themselves, will aid in determining whether or not waterfowl production is a proper management goal of the Warm Springs Ponds, or creation of a new treatment facility for Silver Bow Creek. Additionally, the knowledge will aid in the evaluation of other nonoperating tailings on industrial wastewater treatment facilities and their management for waterfowl production (i.e., the Opportunity Ponds).

- The Montana Department of Fish, Wildlife, and Parks (MDFWP) is interested in a study of this nature as consideration is underway for increasing waterfowl production in the southern Deer Lodge Valley utilizing the existing water resources (Greene 1984b).

A study designed to meet the objectives listed above must consider many aspects of problem definition. These include:

- What are the potential contaminants?
- What are the known effects of these contaminants on wild animals, specifically waterfowl?
- Do the contaminants bioaccumulate?
- In what tissues do the contaminants concentrate--muscle, viscera, bone?
- What tissues are consumed by humans?
- Does seasonal phenomena, such as migration, affect the concentration of contaminants in tissue?
- Is a particular bird species a herbivore or carnivore?
- What are the major food species available?
- What is the source of contamination?
- What is the potential for human exposure to "heavy metals" (i.e., are the birds hunted, and if so, how much, and by how many persons)?

Appendix Table 4.5-1 lists "heavy metal" elements identified as

being potentially toxic to biological systems (EPA 1981; Torrey 1978; Newman 1980) and also lists those "heavy metals" that have been investigated or are planned for investigation in the southern Deer Lodge Valley (Cornish 1984; Phillips 1982; Hydrometrics 1983e). A review of this table indicates that the probable trace elements of highest concern for waterfowl at the Warm Springs Ponds include:

- Arsenic;
- Cadmium;
- Copper;
- Lead;
- Mercury; and
- Zinc.

The following elements are potentially of concern:

- Aluminum;
- Chromium;
- Nickel; and
- Selenium.

Appendix Table 4.5-2 lists documented responses of birds and mammals to acute and chronic exposure to selected air pollutant emissions. Even though this table addresses affects for air emissions, not consumption affects, the body tissue response for some of the elements is the same. In addition to showing the most of

the above listed elements create some physiological reponse, they are also shown to bioaccumulate. Appendix Table 4.5-3 lists those elements identified by the US EPA (1981) as bioaccumulators.

Appendix Table 4.5-4 lists the organs best suited for monitoring avian exposure to "heavy metals." The organs listed are known to concentrate greater element burdens than other tissues. As seen in this table, not all elements of interest to the Silver Bow Creek waterfowl study have recommended tissue types for sampling. However, based on this table, the feathers, liver, and kidneys are probably good tissues to sample for these other elements. Table 4.5-4 also shows that muscle tissue in birds is not the best tissue to analyze to determine "heavy metal" exposure. However, muscle tissue is recommended for sampling in the Warm Springs Ponds Waterfowl Study to evaluate the health hazard to humans consuming waterfowl from the Warm Springs Ponds.

Determining the effect of migration, food chain position (i.e., carnivory or herbivory) and major food species available can all be addressed through judicious study plan design. Figure 3-1 models roughly the flow dynamics contributing to the contamination of waterfowl tissue through the use of contaminate habitat. The recommended study plan does not address the pathways identified in this figure. However, some of the compartments identified in this figure will be studied by other investigations. These include the water compartment, the sediment compartment, and the fish compart-

ment. These data will be available to the waterfowl investigation. The waterfowl investigation will study only the herbivorous waterfowl compartment. If a problem is identified by the waterfowl remedial investigation, then further studies may be recommended to determine the pathway of contamination.

The question of the potential for human exposure to "heavy metals" via consumption of Warm Springs Ponds waterfowl may be addressed through adding on an additional component to the waterfowl investigation for hunter observation and interviews. If a problem is identified, then this study will be recommended.

3.2.3 Agricultural Systems

The recommended approach for the Agricultural Systems Investigation is to acquire field-specific data from those landowners who know of, or strongly suspect, "heavy metals" contamination effects on their soils, crops, or livestock. The means and rationale for obtaining these types of information are discussed in this section.

3.2.3.1 Summit Valley to Whiskey Gulch

It is expected that agricultural impacts within this stream segment will be mitigated by tailings removal or by other remedial actions discussed in Section 3.1 of this report. No specific emphasis on agricultural impacts are recommended for this stream segment.

3.2.3.2 Whiskey Gulch to Mouth of Silver Bow Canyon

No specific emphasis on agricultural impacts are recommended for this stream segment.

3.2.3.3 Silver Bow Canyon to Warm Springs (Settling) Ponds

Food Chain Model

A simplified trace element cycling-food chain model was constructed initially to guide the proceeding work planning efforts. The re-

sulting model, shown in Figure 3-1, allows evaluation of crucial pathways (of element-transfer) from the original source(s) through the terrestrial food chain. In order to apply this model to the present study, the historical toxicants and their sources must be identified. The emissions from the 300 foot stack of the Washoe Reduction Works have been sampled by numerous investigators. Chemical analyses of the "smoke" indicated that it contained sizeable quantities of arsenic (As), copper (Cu), lead (Pb), and zinc (Zn); smaller amounts of bismuth (Bi), manganese (Mn), selenium (Se), and other elements were also observed, (Harkins and Swain 1907). Concomitant sampling of the Clark Fork (Deer Lodge)River indicated that discharge of ore concentration effluents adversely affected the use of such waters for irrigation purposes, probably due to their high water-soluble copper content, (Haywood 1907).

In regards to Figure 3-1, evidence exists that anthropogenic sources of potentially toxic trace elements have entered into the terrestrial ecosystem of the Deer Lodge Valley. Although the present study plan emphasizes the "water pathway," ecologically-based remedial action cannot ignore the "air pathway." Therefore, intelligent evaluation of potential "heavy metal" hazards to agricultural systems and humans requires integration of the forthcoming "river" and "smelter" studies, (e.g., CH_2M Hill 1984). A discussion of toxicity and human health considerations is presented in Appendix 4.4.1.

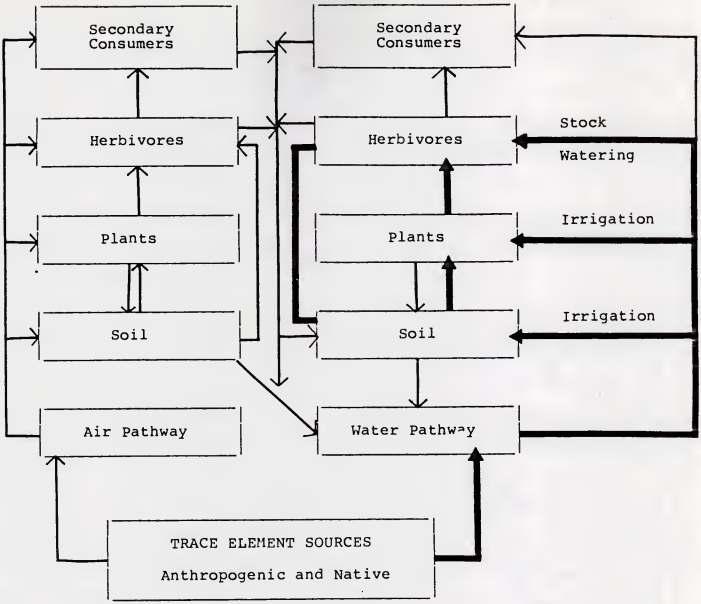


FIGURE 3-1 --FOOD CHAIN/TRACE ELEMENT CYCLING MODEL[a]

Note: a) The bold lines represent those pathways of principal interest to this study; soil-plant interactions, as influenced by the "air pathway" are discussed in MultiTech (1984) and CH_2M Hill (1984).

Irrigation Water, Soils, and Crops

The literature review in Section 4.4.2 documents the need for systematic identification and demarcation of those lands either known or suspected to be affected by "heavy metal" contaminated irrigation waters. Initially, those ditches that received surface waters diverted or pumped from either Silver Bow Creek or Upper Clark Fork River were identified. This effort was accomplished via review of the respective water resource surveys for Silver Bow (Buck et al. 1955a), Deer Lodge (Buck et al. 1955b), and Powell Counties (Buck et al. 1959). Secondly, those owners potentially affected were identified either through inspection of each county's land ownership (plat) books or by interviewing knowledgeable Soil Conservation Service personnel in Deer Lodge (Tribelhorn and Dutton, personal communications). Thirdly, a news release was published on February 28, 1984 in the Montana Standard (Kemmick 1984) that included a solicitation for information pertinent to the irrigated lands study. The initial listing of persons that will be contacted are presented by soil conservation district in Appendix Table 4.5-5. A preliminary estimate of areal extent of affected lands totals to 5380 acres, for the three given counties. The respective county figures are as follows: Silver Bow, 0 acres; Deer Lodge, 1115 acres; and Powell, 4265 acres. Apparently, the combined municipal and industrial effluents discharged by Butte sources into Silver Bow Creek have prevented any attempts at using its waters for regular or flood irrigation purposes (Buck et al. 1955a). The

inclusion of the entire Deer Lodge Valley Conservation District seems appropriate, as waters from the Clark Fork River are pumped or diverted from it throughout this area. Furthermore, "heavy metal" contamination of riparian vegetation by sediments has been documented in the vicinity of Drummond, Montana (Ray 1983). This town is located approximately 10 river miles west of the Granite County-Powell County border, implying that transport of effluents has traveled (historically) at least this far downstream.

Probable Food Chain Contamination Mechanisms

The ultimate concern of this investigation is the potential for bio-accumulation of toxic trace elements stemming from Silver Bow Creek, up through the food chain, culminating in adverse human health effects. The potential mechanisms for accumulation of "heavy metals" are many and varied (Figure 3.1). However, given the setting of agricultural production and types of products in the study area, the following pathways for metal accumulation appear dominant:

- Primary metal uptake in humans is expected to occur either through home garden products utilization or from consumption of livestock tissues or products. In the vicinity of the Washoe Smelter, fugitive dust may be the primary uptake mechanism (by humans and livestock).

- Livestock metal uptake is expected to occur primarily through digestion of metal-enriched forage for some metals (e.g., Cd, Zn), and by soil ingestion for other metals (e.g., Pb).

- Feed, forage, and home garden crop uptake of metals is determined by the degree of soil contamination received from both aerial deposition and eroded tailings materials. "Heavy metal" uptake varies from one element to another and between crop species. The primary source of metal contamination within approximately 10 miles of Anaconda is expected to be historic aerial smelter contamination.

- Soil contamination has resulted primarily from deposition of eroded tailings on the soil surface during past flood or irrigation events. Contamination by smelter effluents appears to be most significant in the Anaconda, Montana area, as judged by areal extent of the mill tailings present within the floodplain of Silver Bow Creek.

Appendix 4.4.3 discusses soil-metal interactions.

Hazard Evaluation Criteria - Irrigation Water, Soils, and Crops

The evaluation of whether or not adverse consequences have resulted from using "heavy metal" contaminated surface water(s) or ground water will be guided by environmental tolerance (or toxicity) criteria gleaned from literature review. Initially, available informa-

tion regarding irrigation water quality, soil characteristics, etc., will be acquired from each potentially affected landowner (see Appendix 4.5-5). Comparison of the acquired data against the pertinent criteria will allow verification of previously documented problems. Furthermore, alleged or unsuspected problems can be identified by comparing sample analytical data against the appropriate criteria. The discussion below provides tentative guidance for evaluation of toxic trace element accumulations, and relevant physiochemical factors, occuring in irrigation waters, soils, and crops. Similar criteria for livestock are presented in the following subsection.

Irrigation is the largest, single-purpose beneficial consumptive use of water in agriculture. Thus, water quality has considerable influence on the value (and safety) of agricultural products requiring such waters. The effects of water quality deterioration or adverse affects of low-quality supplies are more commonly insidious rather than dramatic, (USDI, Federal Water Pollution Control Administration 1968). However, even relatively small-scale improvements in water quality conditions may result in large-scale economic benefits, given the areal extent of the activities involved. Variations and interactions of soils, plants, water and climate, "preclude the establishment of a single set of criteria to evaluate all water quality characteristics for irrigation purposes," (USDI, FWPCA 1968, p. 115). Therefore, the criteria presented in Appendix Table 4.5-6 should be viewed as tentative, but realistic, means for

evaluating any irrigation-related water quality concerns identified within the study area.

Plant nutrient-related properties for a hypothetical uncultivated surface (0-12 inches) soil present within the floodplain-lower stream terrace physiographic unit (MultiTech 1984) were estimated via review of the geochemical literature (e.g, Connor and Shacklette 1975; Dvorak et al. 1978; Siegel 1974; Shacklette et al. 1971). No attempts were made to adjust the properties due to anthropogenic activities (e.g., agricultural management effects such as tillage or fertilization). The corresponding "elevated" estimates are also hypothetical, and could arise from either: 1) native geochemical anomalies or, 2) from Anaconda Smelter emissions or effluents entering air or water pathways (Figure 3-1). The resulting soils-related evaluation criteria are shown in Appendix Table 4.5-7. These criteria represent a credible starting point for assessing (existing or future) data so as to identify potential smelter-related contamination problems. Similarly, "expected" and "elevated" chemical properties for various grass-like and legume plant species are presented in Appendix Table 4.5-8. These values should also be utilized for general guidance when evaluating potential smelter-related concerns. The respective guidelines (for soils and plants) will be refined once "control" data becomes available from the "far-field" (smelter-related) sampling studies, to be implemented presumably in the vicinity of Gold Creek, Montana, (CH_2M Hill 1984).

Hazard Evaluation Criteria - Livestock

Figure 3-1 shows that livestock can ingest toxicants via their water supply, from their forage or feed, and from the soil itself. Appendix Table 4.5-9 presents general criteria for evaluating whether or not a measured quantity of a particular inorganic substance is toxic to livestock, when ingested from their water supply. Appendix Table 4.5-10, Part A, presents species- and tissue-specific data on "normal," "high," and "toxic levels of selected trace elements. The second portion (Part B) of this same table presents available information regarding those dosages required to produce acute or chronic trace element toxicoses, in particular livestock species. Caution must be exercised in using these data, as correct diagnosis of trace element poisoning requires not only chemical analyses of various (if not particular) tissues, but clinical and histopathological evidence as well, (Buck 1969). For example, young horses receiving toxic doses of Pb and Zn may exhibit clinical symptoms of Zn poisoning only, (Willoughby et al. 1972). Furthermore, antagonistic and synergistic interactions between two (or more) elements have not been addressed quantitatively in the above tables. Nevertheless, information in Appendix Table 4.5-10 (livestock-related) will serve two related purposes. First, if the concentration of element "x" is known in tissue "y" of a given species, then the potential for chronic or acute toxicosis can be ascertained. Secondly, if concentrations of element "x" are known in the adversely affected animal's food (including ingested soil) and water supplies,

and if respective dosages can be estimated (i.e., in terms of mg/kg body weight-day), then the probable source(s) of the toxicant can be identified. Hypothetical examples of the second type of evaluation are shown in Appendix Tables 4.5-11 and 4.5-12. Appendix Table 4.5-11 indicates that total body burden of Cu, and possibly Pb, in sheep may be sufficient to cause chronic toxicity~~(ies)~~, especially in particularly sensitive animals. The importance of ingested soil in contributing to the particular trace element burden is demonstrated in Appendix Table 9.5-12. Here, increased Cu levels in soils and forage may be sufficient to cause acute toxicity in sheep, as well as chronic toxicity in cattle. These "worst-case" conditions have resulted also in chronic As and Pb toxicities in sensitive horses. Although the above two examples are hypothetical, the data utilized were taken either from studies performed in the study area, or for very similar areas. The results are sufficient to indicate that testing of the "null hypothesis" (i.e., no presence of trace element toxicities in livestock) appears to be a reasonable investigation.

Remedial Investigation Data Requirements

Data requirements for evaluation of the degree of trace element contamination of agricultural systems and selection of appropriate remedial technologies include soil, crop, and livestock monitoring. Since soil contamination is thought to result mostly from deposition of eroded mill tailings, evaluation of soil chemical characteristics

will be integrated with the tailings investigation (see Section 3.1.4).

Crop tissue analysis should be conducted for the primary feed and forage crops grown. Crop samples will be collected at the same locations as soil samples. Recommended crops to sample include alfalfa, barley, and mixed grass-hay or pasture species. A survey of range and pasture species growing on contaminated soils should be conducted in order to identify any known accumulators of "heavy metals". Tissue analysis of such species should be implemented to document the presence of pasture species with excessive trace element concentrations.

The location and extent of dryland and irrigated crop and forage production areas should be identified and compared to the geographic extent of soil contamination. Sources of irrigation water and irrigation water quality should be assessed to document the potential for future soil contamination being transmitted through the water supply. Finally, any adverse effects to selected livestock species from consuming contaminated water, food supplies, or soil, will be identified and documented. Once the sources of such contamination are identified, pertinent avoidance mechanisms can be developed and implemented.

3.2.3.4 Warm Springs Ponds

No significant agricultural uses are made of the treatment ponds at this time. However, the Montana Department of Fish, Wildlife, and Parks has irrigated small tracts of barley using irrigation water from Pond No. 3.

3.2.3.5 Upper Clark Fork River

The same soil and plant processes affecting the canyon-to-ponds stretch are active along the Clark Fork (subsection 3.2.3.3). A thin, discontinuous layer of tailings sediment was found for several miles downstream of the Warm Springs Ponds on either side of the Clark Fork River by Hydrometrics personnel (1983g). Frequent flooding and irrigation diversion before construction of the Warm Springs Ponds are expected to have caused sediment deposition on most irrigated soils.

Soil, crop, and livestock monitoring outlined in subsection 3.2.3.3 should be implemented also along the Clark Fork River problem area.

3.3 GEOTECHNICAL EVALUATION

The U.S. Army Corps of Engineers (COE) has published guidelines for the classification and for the inspection and evaluation of the safety and potential hazards of dams (USA COE 1975) as defined in the National Dam Inspection Act, Public Law 92-367. All artificial barriers, together with appurtenant works, which impound or divert water and which are: 1) 25 feet or more in height, or 2) have an impounding capacity of 50 acre-feet or more, fall under the jurisdiction of this program.

All dams in this program are classified in accordance to the size and hazard potential. The Warm Springs dams are classified as intermediate in size, which defines all dams having an impoundment capacity greater than 1,000 acre-feet and less than 50,000 acre-feet, and/or a height greater than 40 feet and less than 100 feet. The hazard potential for dams are based upon the probable loss of life and the economic loss which could occur as a result of dam failure. Dams exhibiting the greatest threat to life and economic loss are classified as a high hazard potential.

Complete failure of the Warm Springs Tailings Dams would result in little, if any, loss of life. However, instantaneous discharge of water from the dams could adversely affect the water quality of the Clark Fork River and possibly contaminate downstream lands. Because of the potential to pollute the Clark Fork River drainage, the Warm Springs Tailings Dams are classified as having a high hazard potential.

Studies completed by USA (1980), IECO (1981) and Hydrometrics (1983f) show that the ponds do not have sufficient capacity to accommodate the Probable Maximum Flood (PMF). The naturally occurring man-made boundaries at the terminus of Silver Bow Creek restrict the lateral extent of the flood plain and as a result, the PMF would overtop the Warm Spring Tailings Dams. This would undoubtedly result in a breach of the dam(s) and consequently washout most of the embankment material, compounding the dam failure.

The dissipation of energy and loss of momentum of the PMF flood wave as it enters the Clark Fork River drainage cannot be accurately determined due to the many assumptions and iterations which would have to be considered. Consequently, total and/or catastrophic failure of the Warm Springs Tailing Dam is unpredictable. It is doubtful that the existing dams would be completely washed away and that total failure would occur. The release of water and sediment contained in the Warm Springs Tailing Dam would be substantial, however, and could adversely affect the quality of water and land downstream.

3.3.1 Previous Geotechnical Investigations

The COE made a limited investigation of the Warm Springs Tailings Dam in 1980. This inspection was completely in accordance to the procedure and guidelines established by the National Dam Inspection Act, Public Law 92-367. Under these guidelines all non-Federal dams must be inspected under a two-phase study procedure. The

Phase I Study was completed by the COE and consisted of a reconnaissance inspection and preliminary investigation to determine the general safety conditions of the dam, the need to establish an emergency warning system and escape plan, and the need for additional studies or detailed investigation(s).

The Phase II Study includes all additional studies necessary to evaluate the safety of the dam. Additional studies would necessitate a more detailed on-site inspection, facility measurements, foundation investigation, materials sampling and testing, hydrologic evaluation, and stability analyses. The Phase II Study was completed by International Engineering Company, Inc. (IECO) in March, 1981. Northern Testing Laboratories (NTL) completed much of the geotechnical drilling, sampling, and testing and stability analyses for IECO.

A part of a long-term environmental rehabilitation study of the Butte-Anaconda area for the Anaconda Minerals Company (AMC), Hydrometrics (1983f) examined the hydrologic impacts to the Warm Springs Ponds. Hydrometrics concluded that the Warm Springs Tailings Ponds and the by-pass channel cannot accommodate the projected PMF. Additionally, Hydrometrics stated that the ponds are nearly at capacity and that additional storage is limited; therefore, their useful function as settling ponds is also limited. This being the case, the cost and benefits of modification to the ponds may not be cost effective in terms of their future usefulness and the potential cost of damage to the Upper Clark Fork River drainage.

The COE investigation identified the Warm Springs Tailings Ponds as intermediate in size with a high hazard potential due to the possible environmental degradation of the Clark Fork River drainage and possible resultant economic loss. The dam evaluation guidelines (USA COE 1975) state that large capacity dams with a high downstream hazard potential be capable of safely storing and/or passing a full PMF. The COE concluded that the existing ponds and by-pass channel would not handle the projected PMF and that overtopping would occur, resulting in dam failure. This potential resulted in the following recommendations:

- An emergency warning and evaluation plan should be developed and implemented;
- Procedures should be developed to remove stop logs from Dams Nos. 2 and 3 during periods of high flow;
- Detailed studies should be conducted to evaluate the probable environmental consequences resulting from dam failure;
- Establish a program to monitor dam seepage; and
- A geotechnical investigation should be conducted to assess embankment stability as a result of continued seepage and/or seismic disturbance.

The recommendation of the COE investigation (1980) prompted the AMC to initiate a detailed hydrologic and geotechnical study in accordance with the Phase II Dam Inspection Guidelines. This study was completed by IECO (1981). The hydrologic portion of this investigation more accurately assessed the hydrologic conditions

and projected the PMF. Based upon the projected PMF, IECO examined the existing structures and the modifications necessary to safely pass the PMF. The geotechnical portion of this study investigated the geologic and hydrogeologic conditions of the site and foundation, the embankment materials and materials properties, measured seepage, evaluated the seismicity of the site, and computed numerous stability analyses to evaluate dam embankment stability.

3.3.1.1 Hydrological Evaluation

IECO concluded that the existing facilities would not handle the PMF but that a flood of the magnitude of the PMF would be nearly unaffected by the relative insignificant delay and attenuation effects due to routing through the Warm Springs Tailings Ponds. A scenario of the effect and routing of the PMF flow through the pond area is provided in their report, assuming the dam embankments do not fail, which is a possibility. They state, however, that failure of Dam No. 3 would certainly result in failure of the remaining two. Thus, they conclude that Silver Bow Creek PMF has a high probability of causing general failure of all three ponds.

3.3.1.2 Geotechnical Study

The geotechnical investigation evaluated the pond site conditions; foundation and embankment materials properties; and the stability of the three dams. Field and laboratory investigations and testing were completed, seismicity studies made, and static and pseudo-static

stability analyses performed. A field exploration and sampling program consisting of 40 drill holes was completed in the pond area. Test holes were drilled to depths ranging from 19 to 70 feet. Samples were collected and logged, field and laboratory classifications made, and several laboratory tests completed to determine materials characteristics and/or engineering properties. Twenty-seven of the 40 holes drilled were completed as piezometers to measure ground water levels and establish phreatic surfaces. Water levels were measured in June and October 1980.

Results of the geotechnical study show the embankment materials to be clayey-silts, silty-sands, and sandy gravels. The inner core consists primarily of silty-clay and clay-silt. The materials are firm-to-medium, dense, with a low-to-moderate penetration resistance. The permeability of the materials is low and varies from 1×10^{-4} to 3×10^{-4} centimeters per second which is comparable to the permeability of silty sand.

Ground water was encountered in 39 of the 40 test holes drilled. Water levels ranged from less than one foot below the ground surface to as much as 30 feet below the ground surface, depending upon the location of the hole relative to the embankment. The presence of ground water in the test holes and the existence of numerous wet areas along the downstream toes of the embankments indicate that seepage through the dams is somewhat prevalent, although IECO concluded that it does not appear to be a present threat to the long-term performance of the dams.

3.3.1.3 Seismicity

Warm Springs Tailings Ponds are located in a fairly active seismic zone, although the site itself is not located near any active faults; nor have any surface fractures been noted in the vicinity of the ponds. The closest fault and the one most likely to have the greatest seismic affects on the Warm Springs Ponds is the Continental Fault near Butte. IECO (1981) reports that this fault has the capacity to produce and earthquake with a magnitude of 6.9 on the Richter Scale. An earthquake of this magnitude could generate a mean peak acceleration of approximately 0.23 (g) at the Warm Springs site with a predominant period of 0.3 seconds and a duration of shaking lasting 25 seconds. A seismic disturbance of this magnitude and duration could cause liquefaction and reduce the stability of the dam resulting in toe and/or slope embankment failure; increased seepage; and partial destruction of the hydraulic structures and diversion systems. The probability of these events occurring is highly dependent on the composition, density, and moisture content of the embankment materials. The geotechnical data listed in the IECO (1981) report suggest that liquefaction would probably not occur.

3.3.1.4 Stability Analyses

Stability analyses using four different embankment cross-sections were made to determine the potential for embankment failure and the factor of safety against sliding. Two methods of analyses were

performed for each cross-sectional area. The first analysis evaluated stability assuming steady-state seepage; and the second analysis evaluated stability assuming a seismic psuedo-static condition. Cross-sections included one from Dam No. 1, one from Dam No. 2, and two from Dam No. 3. The minimum factors of safety computed from the analyses ranged from less than 0.83 for the seismic affects on an embankment cross-section for Dam No. 3, upwards to 2.85 for steady state seepage on a cross-section through Dam No. 3.

Generally accepted factors of safety standards for steady-state seepage and seismic conditions are 1.5 and 1.0, respectively. Several computer factors of safety were below 1 which included cross-sections through Dams Nos. 2 and 3. The most serious threat and the most likely probability of failure results from a seismic disturbance on a cross-section through Dam No. 3. The safety factors were raised to acceptable levels upon several hypothetical conditions which included the addition of three to four foot berms placed at the toe of the embankments.

3.3.1.5 Conclusions and Recommendations

The IECO report (1981) recommended the following:

- Portions of the dam embankments should be raised to permit passage of flood water from the Silver Bow Creek drainage through the by-pass channel;

- Erosion protection should be provided on the face of the embankments along the by-pass;
- Emergency spillways must be designed and constructed at each pond to control flooding and prevent overtopping the embankment; and
- Stabilizing berms should be constructed along the toe of Dams Nos. 2 and 3 to improve the safety factor and reduce the potential for embankment failure.

As of this date, none of the remedial measures recommended by IECO have been completed.

The IECO (1981) report only addressed the flood hazard associated with the Warm Springs Ponds. It is recommended that a study be performed as part of the remedial investigation to determine the operational life span and efficiency of the Warm Springs Ponds. A study of this type would need to address:

- Available volume of solid storage,
- Rate of solid deposition, and
- Existing and planned operational procedures.

A study designed to address these questions is outlined in Section 2.0.

4.0 APPENDICES

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4.2 ANNOTATED BIBLIOGRAPHY

An annotated bibliography of documents, reports, and letters is available from MultiTech, P.O. Box 4078, Butte, MT. (494-5319).

4.3 PERSONS AND ORGANIZATIONS CONTACTED

Those persons and organizations contacted for information on Silver Bow Creek are listed in the References Cited, Section 4.1, if their information was used in this report.

4.4 SUPPORTING TEXT

4.4.1 Toxicity and Human Health Considerations

Before a particular substance can be considered "toxic," its physiochemical form and dosage must be defined. For example, the LD_{50} (oral) values for mercuric and mercurous chlorides for rats are 37 mg/kg and 210 mg/kg, respectively (McKee and Wolf 1963). Furthermore, the biological and physiochemical properties of the matrix material (e.g., water, soil, food) must be considered also. The level of biologically available metal ions present in a given irrigation water will be influenced by such factors as: pH, water hardness, complexing agents, and reactions with the bottom sediments, (Manahan 1979). Upon transfer to the soil, the particular ion's "plant-availability" is influenced by a number of inorganic factors as well as biochemical-physiological adaptations of the particular

plant species. The inorganic factors include pH, redox potential plus competing anion and cation concentrations (Bohn, et al. 1979; Jenne and Luoma 1977). The probability that a given ion is uptaken into the particular plant is determined by such factors as: the characteristics of the soil solution, species-specific nutritional requirements, extent and depth of rooting, plus seasonally-varying growth and transpiration rates, (Lisk 1972).

The fate of the ion, once absorbed into the plant, is influenced by various genetically based factors. For example, Zn and Cd are readily translocated to aerial (leafy) tissues, even though the latter is a non-essential element and is relatively toxic to plant growth; it is sumised that each element's ionic properties are sufficiently similar that Cd is not excluded effectively from the zinc transport pathway(s). However, the adverse affects of Pb--another non-essential element--are mitigated largely by immobilization in roots. Moreover, with the exception of Mn and perhaps molybdenum, (Mo), legumes generally accumulate more of most trace elements, especially cobalt (Co), Cu, iron (Fe), nickel (Ni), and Zn than grasses grown in the same soil, (Horvath 1972).

The sensitivity of a particular livestock species to agiven element is also determined by its physiochemical form, dosage and route of ingestion, and various homeostatic mechanisms that either minimize absorption or maximize excretion rates, (Underwood 1977). The human effects of consuming toxic doses of trace elements is usually more difficult to assess, given that the food supply is derived

from many geochemical areas and is processed in various ways. Acute toxicities are judged to be of rare occurrence, while localized chronic toxicities should be avoidable by careful monitoring of irrigation water, crops and livestock tissues. These "lower" components of the terrestrial food chain serve as buffers, mitigating largely the adverse affects of toxic trace element transfer processes prior to impacting human health and safety.

4.4.2 Literature Review

Irrigated Lands

The discharge of mill tailings into the Clark Fork (Deer Lodge) River, and subsequent adverse effect on irrigation has been recognized for some time. J. K. Haywood (1907) observed that,

> "...a large number of the farmers say that it is injurious and prefer to get their water from small creeks coming down from the mountains on either side, and only use the Deer Lodge River when it is absolutely necessary," (Haywood 1907, p. 1005).

In response to these concerns, Haywood tested the hypothesis that finely divided insoluble copper sulfide (released from the smelter works) was oxidized to various soluble salts, notably copper sulfate. Waste water from the works, plus samples from various locations downstream of the smelter, were acquired and analyzed for "insoluble"

and "soluble" copper. The results of these investigations are shown in Table 4-1. With reference to (historically) contemporary research findings, Haywood concluded that Clark Fork River waters were not fit for irrigation purposes and would, "eventually, if not at once, seriously injure land to which it was applied," (Haywood 1907, p. 1009). Copper tolerance has been set at 0.2 mg/l for irrigation waters used continuously on all soils, but especially those soils having sandy textures and containing very low organic matter, (USDI Federal Water Pollution Control Administration 1968). For short-term use on fine-textured soils, the recommended limit is at least 5 mg/l, (ibid.).

It was observed also that soils present along the edges of irrigation ditches, 12 miles and more below the effluent discharge point, were colored distinctly blue with copper. Surface soil on a farm located 10 to 12 miles below the inlet of tailings, and which received irrigation water from the Clark Fork River, was examined via insertion of a knife blade. When withdrawn from the soil, the blade had been coated with copper, (Haywood 1907, p. 1009). The upper foot of various soil profiles (and sites) were sampled during the summers of 1906 and 1907. The results of the analyses for "insoluble" and "soluble" copper are shown in Parts A and B, respectively, of Table 4-2, (Haywood 1910). The variations observed (between sampling periods) were explained by such factors as uneven distribution of metal over a given field, rainfall, irrigation, "amount of oxidation," season, etc., (Haywood 1910, p. 35).

TABLE 4-1.--COPPER CONTENT OF WATER SAMPLES ACQUIRED BY J. K. HAYWOOD, 1906

Sampling Site Description	Copper Concentration (ppm) "Insoluble"	"Soluble"
Waste water of smelter	31.0	0.05
Clark Fork River, 1-1/2 miles below entrance of smelter waste	12.1	0.77
Clark Fork River, 6 miles below entrance of smelter waste	12.0	0.15
Clark Fork River, 8 miles below entrance of smelter waste	6.4	0.22
Clark Fork River at Deer Lodge, about 16 to 18 miles below entrance of smelter waste	3.1	0.51

Source: J. K. Haywood 1907, p. 1008.

TABLE 4-2.--COPPER CONTENT OF SURFACE SOILS SAMPLED IN 1906 AND 1907

PART A. ANALYTICAL RESULTS FOR THE 1906 SAMPLES

Serial No.	Origin and Description of Sample	Copper Concentration (ppm) "Insoluble"	"Soluble"
4185	8 1/2 miles NE of smelter; irrigated by Clark Fork River.	1,549.4	20.4
4183	9 1/2 miles NE of smelter; irrigated 12 years by Clark Fork River.	458.4	3.4
4184	12 miles NE of smelter; irrigated by Clark Fork River.	1,451.6	118.2
4182	12 miles NE of smelter; irrigated by Clark Fork River.	2,790.8	118.2
4186	14 miles NE of smelter; irrigated 16 years by Clark Fork River.	870.4	7.1
4165	15 miles W of smelter; not irrigated by Clark Fork River.	Trace	None
4163	10 miles SW of smelter and about 2 miles beyond divide; not irrigated by Clark Fork River.	13.0	Trace

PART B. ANALYTICAL RESULTS FOR THE 1907 SAMPLES

Serial No.	Origin and Description of Sample	Copper Concentration (ppm) "Insoluble"	"Soluble"
4871	8 miles NE of smelter; flooded by Clark Fork River; no sample taken from this field in 1906.	10,018.9	1.1
4872	8 1/2 miles NE of smelter; irrigated by Clark Fork River; sample no. 4185 taken from this field (in 1906).	979.9	1.1
4873	9 1/2 miles NE of smelter; irrigated twelve years by Clark Fork River; sample no. 4183 taken from this field (in 1906).	312.9	2.1
4874	12 miles NE of smelter; irrigated by Clark Fork River; sample no. 4184 taken from this field (in 1906).	98.7	2.1

TABLE 4-2.--COPPER CONTENT OF SURFACE SOILS SAMPLED IN 1906 AND 1907 (CONTINUED)

PART B. ANALYTICAL RESULTS FOR THE 1907 SAMPLES (CONTINUED)

Serial No.	Origin and Description of Sample	Copper Concentration (ppm) "Insoluble"	"Soluble"
4875	12 miles NE of smelter; irrigated by Clark Fork River; sample no. 4182 taken from this field (in 1906).	624.6	10.4
4876	14 miles NE of smelter; irrigated 16 years by Clark Fork River; sample no. 4186 taken from this field (in 1906).	739.8	5.2

Source: Tables X and XI (p. 34) in J. K. Haywood 1910.

At that time, it had been suggested that soils irrigated by the Clark Fork River were already unfit for growing crops, given the supposed presence of black alkali; therefore, the addition of copper could not make matters any worse. However, the analysis for soluble salt content of surface (0-12 inches) irrigated soils indicated that none of them contained, "any black alkali or a sufficient amount of white alkali to be injurious to ordinary farm crops," (Haywood 1910, p. 35).

There are few published studies of irrigation waters contaminated by smelter effluents, within the Upper Clark Fork River, since publication of those investigations by Haywood. The water resources survey document for Powell County noted that three general problems are associated with irrigated soils in the county (Buck et al. 1959). These concerns included: 1) shallow or very gravelly or cobbly soils having low production potential, 2) soils with a combined problem of wetness and salinity or very high lime, and 3) "soils which are toxic to plants because they have been irrigated with water containing smelter waste that is charged with toxic minerals," (Buck et al. 1959, p. 17). Although it was recommended that further studies be performed on soils damaged by smelter wastes, published documentation regarding reclamation feasibility assessments and attempted methodologies appear to be negligible. Clearly, the concern regarding water quality-sediment problems remains, as indicated by oblique comments contained in the Deer Lodge Valley Conservation District's Long Range Program, (1982, p. 9).

Livestock

Numerous instances of livestock morbidity and mortality were reported by farmers raising such animals within the "smoke zone" of the Washoe Smelter, within one year of its initiation of operations. In response to allegations of arsenic poisoning via consumption of contaminated grass and hay, The Anaconda Company constructed a large scale settling chamber-flue-stack system, (Anonymous 1903). After a year and a half of operation, the company claimed that sulfur dioxide and arsenic emissions were no longer a problem. However, the farmers continued their assertions that livestock and crops were still being damaged (as before), although the pattern of adverse affects had changed somewhat. W. D. Harkins and R. E. Swain investigated the physiochemical properties of the stack emissions in August 1905, and concluded that considerable quantities of copper and arsenic were escaping the dust control system. In regards to arsenic, it appeared as though the flue terminated just where it became efficient at condensing and settling the metalloid trioxide (Harkins and Swain 1907, p. 995).

These two investigators gathered and analyzed hay and native grass samples for their arsenic and copper contents during the period November 1902 through October 1907. Interpretation of the data indicated two important conclusions. First, the arsenic levels in vegetation correlated well with meteorological (plume dispersion) conditions. Secondly, surface adsorption of Arsenic appeared to be more important than absorption through roots, as the element

continued to accumulate (over time) even after the particular plant had ceased growth or had died. Although elevated arsenic levels were observed in surface soils, but not at depths of 12 to 15 inches, the investigators concluded that dust from soil was not contributing significantly to those quantities of Arsenic found in dust adhering to hay, (Swain and Harkins 1908).

Various cases of acute or chronic arsenic toxicosis in cows, horses, and sheep were investigated also by Swain and Harkins (1908) during the period 1902-1905. Several important conclusions were made from their observations. First, although Arsenic concentrations were greater in those animals kept relatively near the smelter, the condition of the animal was the more important factor in determining the amount of arsenic retained by the tissues. Secondly, those animals native to the area appeared to have greater tolerance to Arsenic than did animals shipped in from elsewhere. R. J. Formad et al. investigated 21 ranches, all located within 12 miles of the smelter and supposedly affected by smelter smoke, during the period October 26 through December 8, 1906, (Formad 1908). Clinical symptoms and post-mortem observations on 22 domestic animals indicated various stages of chronic arsenic poisoning. Histologic examinations of various tissues showed vascular and epithelial changes as well as connective tissue proliferation common to inflammatory-type irritants. Subsequent chemical analyses revealed the irritant to be arsenic. The author concluded that livestock pasturing within the Deer Lodge Valley become unthrifty, and suffer from superficial

(e.g., "sore nose" syndrome) and internal maladies (e.g., digestive disturbances) due to consumption of As-contaminated forage or feed.

In response to continued private and Federal law suits, The Anaconda Company installed various air pollution control devices during the period 1912 through 1919; such facilities included Cottrell-type electrostatic precipitators and a 585 foot stack, (Dunn 1914, Laist 1933). Furthermore, by 1925 the Company had eliminated most of its problems with affected landowners via purchase of their respective holdings, (MacMillan 1973). These actions, in conjunction with adaptations in agricultural management practices, apparently mitigated the "smoke problem" regarding livestock, as no systematic investigation of such concerns can be found in the open literature (for the Deer Lodge Valley) after 1910. The available time for preparing this document was insufficient for perusal of the approximately 25,000 pages of records associated with the litigation of F. J. Bliss et al. versus The Anaconda Copper Mining Company and the Washoe Copper Mining Company, (Fulton 1915). These records may contain additional laboratory and field studies regarding "heavy metal" affects on the study area's agricultural resources.

4.4.3 Soil-Metal Interactions

It is expected that little movement of metals has occurred from the surficially contaminated layer of sediments into the native soils. Korte et al. (1975) found that limited metal movement occurred even

with acid leachate. Metals differed in their tendency to leach in the following order:

$$Mn >> Co = Ni = Zn > Cu = Cr > Pb = Cd$$

This series indicates that, of the problem metals in the study area, Zn and Mn are the most soluble; Cu, Pb, and Cd are recognized as being less-soluble. Brown and Thomas (1983) measured metal movement using non-acidic leachate and found a similar order of solubility, except that Cu was most soluble. However, no metals were detected to flow as much as 1.5 m (down) through the soil in their study. "Heavy metals" have been found to become bound to soil components like clays, manganese and iron oxides, phosphates (forming insoluble salts of Pb and Zn), and to calcium carbonate, (Pickering 1983). As a result, most metal contaminants present in eroded sediments are expected to remain in the upper rooting zone. Here, their potential to inhibit plant growth and be ingested by livestock is enhanced.

Biological systems appear to have developed mechanisms to avoid accumulation of metals in the food chain. The term "soil-plant barrier" to metal uptake has been used to describe these processes, (Parr et al. 1983). The soil-plant barrier concept encompasses the following processes which limit food chain accumulation: 1) insolubility of an element in soil which prevents its uptake; 2) immobility of an element in the plant root, thus preventing translocation to aerial tissues; and 3) phytotoxicity caused by a critical element

before plant tissue concentrations reach levels hazardous for animals consuming it.

At low pH, like those found in eroded sediments on agricultural soils, the solubility of Zn, Cu, Al, Mn and other metals increases greatly, thus short-circuiting the above processes (preventing metal accumulation). Elements like Zn, Cu, Mn, Cd, Mo, Se, As, and B may be readily taken up by plants and may then be translocated to the plant top, (Parr et al. 1983). However, phytotoxicity will usually prevent hazardous accumulation of these metals, with the exception of Mo and Cd. Many elements are not absorbed by plant roots or are not translocated past the rooting zone even in contaminated soils (e.g., Fe, Pb, Hg, As, Cr). Thus, the risk of accumulation in the food chain is reduced.

Different crops or plant species differ in their tendency to uptake elements. An extreme example of this short-circuiting of the soil-plant barrier is called "hyperaccumulation", (Reeves and Brook 1983). Numerous hyperaccumulators of such metals as nickel, copper, cobalt, zinc, and lead have been discovered which contain 1,000 to 10,000 ppm of these elements in above ground plant tissue. Most hyperaccumulators are forbs, with the majority belonging to the genus Alyssum. Development of guidelines for safe utilization of municipal sludge has resulted in the identification of differential metal uptake and transport in a variety of crops, (Garcia et al. 1981).

Arsenic accumulation to levels hazardous to livestock is an unlikely occurrence due to the potential for prior phytotoxicity, (Parr et al. 1983). Development of As tolerance in certain grasses has been found near mining areas in Great Britain, (Porter and Peterson 1977). Such As-tolerant plant materials may accumulate excessive As levels in plant tops.

The potential for excessive Cd accumulation is of great concern, as Cd is often the element which most limits the application rate of municipal sludge, given its tendency to accumulate in the food chain. Roberts and Johnson (1978) found Cd accumulated the most in a terrestrial food chain near old lead-zinc mines. Zinc accumulation was limited due to the biological utilization and essential nutritional status of Zn.

Lead accumulates in lower trophic levels (in the ecosystem) and is not transferred through the food chain as was Cd. Cadmium accumulation in edible portions of certain garden produce (e.g., spinach, turnip, tomato, lettuce, chard, radish, and carrot) was especially acute. Therefore, garden produce is a critical pathway of human Cd uptake, (Parr et al. 1983).

Copper accumulation in plants to levels toxic for livestock consumption is unlikely. Copper phytotoxicity would commonly occur before this threshold was reached. A more frequent concern is the inducement of copper deficiency in ruminants by excessive dietary levels of elements like Mo, Zn, Fe, or SO_4^{-2} ion.

Lead uptake by plants is limited, as most lead is immediately immobilized within the root system. A more common pathway of lead accumulation is through soil ingestion by grazing animals, (Thornton and Abrahams 1981).

Molybdenum is a plant-essential element which is readily taken up and translocated to the plant top. Relatively low concentrations of plant Mo can induce copper deficiency or "molybdenosis" in ruminants. Concentrations of extractable-Mo in the slightly-to-strongly-acidic sediments in agricultural soils were low. However, liming of these wastes, a potential mitigative measure, would increase Mo solubility, thus increasing its potential for uptake.

Zinc is a plant-essential nutrient which is often deficient in plants and in livestock diets in the western United States. It has been suggested that some elevation of Zn levels in forage could be beneficial in many areas. However, Zn toxicity is blamed for substantial small grain and forage yield reduction in most agricultural areas along Silver Bow Creek. As such, the potential for livestock accumulation of excessive Zn appears likely. Forage species like alfalfa tend to accumulate tissue-Zn, while wheat (Garcia et al. 1981) tends to accumulate Zn in the grain (edible) portion of the plant. Many leafy garden vegetables also accumulate Zn. Excessive levels of Cu and Fe tend to reduce the risk of Zn accumulation, however.

Many techniques could be used to mitigate the effects of contamination of agricultural soils. Contamination treatment for irrigation water, soil, crops, and livestock in the Upper Clark Fork area falls into three broad categories: soil treatment, water treatment, and crop management. These treatment methods are discussed in the Preliminary Remedial Technology Review Report for this project (MultiTech and Stiller and Associates 1984).

4.4.4 Surface Water Methods

4.4.4.1 Surface Water: Sample Site Selection

Several factors are involved in the proper selection of surface water sampling sites, including the following: accessibility; flow; mixing; physical characteristics of the stream reach; and locations of point and diffuse sources of contamination. In the case of Silver Bow Creek and Clark Fork River, where dissolved constituents may be prominent, dispersion depends on the vertical and lateral mixing within the cross section of the stream.

Accessibility to any sampling site is important, especially during foul weather and if land ownership problems are of concern. Bridges are usually a good choice for sampling sites, especially for rivers the size of the Clark Fork. Because of the need to obtain synchronous samples from a large number of sites in this investigation, rapid access to sample sites is paramount.

Flow data are necessarily obtained with each sample collection. Adequate discharge data are essential for calculating total loads carried by the stream. Methods for measuring discharge are described in Section 4.4.4.5.

Locating sampling sites near known point source or tributary inputs involves careful scrutiny to identify appropriate mixing zones. Representative samples will be obtained only if the sampling site

is located above point source or tributary inputs or far enough below the input to provide for complete mixing. When non-point sources are prominent, such as the case of tailings deposits adjacent to Silver Bow Creek and Clark Fork River, selecting a sampling site to obtain a representative sample is difficult. Because of the line inputs to the stream, the quality of the water in cross-section is likely to change significantly, especially in areas near the stream banks. Sampling techniques to account for these variabilities are described below.

4.4.4.2 Surface Water: Water Quality Sampling

Sampling collection techniques in surface water vary considerably from simple grab sampling to more sophisticated mutipoint sampling techniques known as the equal-discharge-increment (EDI) method, or the equal-width-increment (EWI) method (USDI 1977). The number and types of samples to be obtained will be dependent on physical features of the stream, discharge, and the extent of lateral mixing.

Grab sampling is the most common method of sample collection. Water is obtained by filling a container held just beneath the surface of a body of water. A weighted holder is sometimes used to allow a sample bottle to be lowered to any described depth, opened for filling, and then closed and returned to the surface.

Other sampling methods involve obtaining depth-integrated samples. Types of depth-integrated techniques include the EWI and EDI methods.

Depth-integration is used to collect a water-sediment sample that is weighted according to velocity at each increment of depth. For small flows, a depth-integrated sample taken at the centroid of flow is usually adequate. For larger flows, however, the EDI and EWI methods should be used. In using the EDI method, it is necessary to determine the total discharge across the stream channel, subdivide the cross section according to incremental discharges, and then obtain depthintegrated samples from each of the subdivisions. The EWI method is similar to the EDI technique except incremental widths of the channel cross section are used in lieu of discharge. The samples collected in each vertical are then composited into a single sample representative of the flow at a particular sample site.

Depth-integrated sampling utilizing either the EWI or EDI methods may prove useful at sampling sites on Silver Bow Creek and Clark Fork River. This is because of the size of the Clark Fork River and the diffuse, nonpoint sources that may affect Silver Bow Creek.

Flow composite sampling may prove useful in evaluating the effects of point source inputs to a receiving water body when the point source inputs occur intermittently and when the point source water quality itself varies over the discharge period. Depth-integrated samples are taken at evenly spaced time intervals over the period of discharge. Concurrent with the taking of each sample, a flow measurement is made. A flow hydrograph for the period of discharge can thus be constructed from the individual flow measurements.

The flow composite sample is therefore composed of the collected sample weighted proportionate to the total discharge volume calculated from the hydrograph.

4.4.4.3 Surface Water: Sampling Devices

Devices used in collecting surface water samples include containers and depth-integrating samplers. Types and capabilities of containers necessary for this study are described in the QA/QC Plan.

Several depth-integrating samplers are available for the purpose of collecting representative water samples. In shallow streams that can be waded, such as Silver Bow Creek, devices like the US DH-48 suspended sediment sampler can be used successfully. For deeper streams, such as Clark Fork River, devices like the US DH-59 sediment sampler can be used. This sampler was designed to be suspended by a hand-held rope in water too deep to wade.

The bedload component of sediment discharge in Silver Bow Creek and its tributaries will be measured with a device such as the Helley-Smith Bedload Sampler. Such measurements will only be made if the bedload component of total sediment discharge is significant, based upon preliminary field observations and analysis of particle size distributions of streambed material and cut banks of eroded tailings. Calibration of the Helley-Smith sampler will be in accordance with Manufacturer's directions and Emmett (1980).

Several types of continuous or automatic samplers are available which have been designed to collect water samples at a rate proportional to either discharge or time. These types of samplers may be necessary to characterize changes in water quality for such occurences as snowmelt or precipitation events.

4.4.4.4 Surface Water: Sample Handling and Preservation

Surface water sample handling and preservation techniques are described in the QA/QC Plan.

4.4.4.5 Surface Water: Discharge Measurement Techniques & Devices

Several methods are widely used in making discharge measurements in streams and rivers. Common methods include volumetric techniques, velocity - area techniques, and indirect measurements. No one method is appropriate for all site or flow conditions. It is important, therefore, that field personnel are well trained in discharge measurement methods and equipment which best meet a given flow situation.

Volumetric Method

The volumetric method of discharge measurement is considered the most accurate of all methods, with the possible exception of weighing (Corbett and other 1945). The method consists simply of observing the time required to fill a container of known capacity.

A modification of this method has been used in measuring the discharge over broad-crested weirs and dams where depths are shallow and flow is otherwise unmeasureable (Bureau of Reclamation 1967).

Velocity-Area Method

The velocity-area method of discharge measurement utilizes direct measurements of average velocities and cross-sectional areas at discrete sections in the stream. The product of these measurements is then summed to produce a composite discharge value for the stream. A rotating element current meter is typically used for velocity measurements.

The velocity-area technique frequently uses measurements made by or from bridges. Current-meter measurements by wading are usually made if the stream is shallow and relatively slow moving. A tagline is typically stretched across the stream to locate the measurement sections. Current meters such as the Price-Type AA or A should be used when depths exceed 1.5 feet and current meters such as the Pricepygmy meter should be used when depths are between 0.3 and 1.5 feet and velocities are below 2.5 feet per second (USDI 1977). Measurement depths should be based on current meter manufacturers' recommendations.

Current-meter measurements from bridges offer some problems in obtaining reliable discharge data. These problems include bridge piers which obstruct normal flow patterns of the stream. Additional

stream sections will be measured in the vicinity of bridge piers to account for any such difficulties.

Width and sounding locations are generally made from permanent markings identified on the bridge. Soundings are made by suspending a weighted current-meter (such as a Price-type-AA) from a crane or similar support mechanism. Depth of the meter in the water and corrections for the angle of the meter in the stream should be based on manufacturers' recommendations.

Indirect Methods

Discharge measurements are sometimes made after a flow event has occurred. Methods used to measure flow indirectly include slope-area methods, flow measurements at contracted openings, and flow through culverts. Indirect methods of determining peak discharges are based on hydraulic equations which relate the discharge to the water-surface profile and to the geometry of the channel. Data necessary to utilize these equations are obtained by conducting field surveys after a highflow event to determine the location and elevation of high-water marks and to define channel characterisitics (Benson and Dalrymple 1968).

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4.4.4.6 Surface Water: Continuous Record Gaging Stations

Gaging stations are installed to provide a continuous record of variations in stream stage which can be related to a continuous record of discharge at a particular site. To establish this relation, it is necessary to make an adequate number of discharge measurements in conjunction with simultaneous readings of effective gage heights (Corbett and others 1945).

The gaging site will be located in an area where physical and hydraulic features at the site will allow an accurate stage-discharge relationship. A desired site would exhibit channel stability and would be sensitive to changes with variations in stage.

Basic components to a gaging station include the instrument shelter, the stilling well, and intakes which connect the stilling well to the stream. The instrument shelter provides protection and security for gages, instruments, and other equipment at the station. Various types of shelters are available, or several designs are available for fabrication. The most important concerns are that the instrument shelter is functional, convenient, and of adequate size to house all equipment.

A stilling well is used to relate stage in the stream to water level in the well. A continuous recorder (such as the Stevens F-1 type) is placed above the stilling well to monitor fluctuations in stream stage. The stilling well will meet the following criteria, as outlined by USDI (1977):

- have sufficient height to accomodate the entire range in stage at the station;
- have intake pipes at various elevations to accomodate varying stages and silt contents;
- have intake pipes of sufficient size to assure water level in the well does not lag behind the changing stage in the river; and,
- be of sufficient size to accomodate heating apparatuses for the cold weather recording process.

The lowest intake pipe will be located about 0.5 feet lower than the lowest expected stage. Provisions will be made such that intakes are routinely cleaned or flushed.

4.4.4.7 Surface Water: Calibrated Control Structures

In a situation where repeated current metering is impractical, a precalibrated control structure may be the best method of discharge measurement. Types of calibrated control structures include flumes and weirs.

A variety of flumes are available to measure discharge under a variety of flow regimes. A particular type of flume will be selected based on sediment movement, rate of change of stage, expected discharge frequency relation, shape of the stream cross section compared to the flume, and construction cost (USDI 1977). Discharge tables for various types and sizes of flumes, as well as corrections for submerged conditions, are provided by the U.S. Bureau of Reclamation (1967). Continuous recorders will be installed on flumes in a fashion similar to that described for gaging stations (See Section 4.4.4.6).

A weir is an overflow structure built across an open channel used to measure the rate of flow of water (U.S. Bureau of Reclamation 1967). The discharge is a function of water in the pool upstream from the crest relative to the crest elevation, and the shape and size of the weir (USDI 1977). Weirs are generally not used in

areas with high sediment yield and may not be practical in the study area.

4.4.5 Ground Water Methods

4.4.5.1 Well Installation

Monitoring wells utilized for this study will be constructed as shown in Figure 4-1. Well designs will be equivalent for both 4-inch and 2-inch diameter wells. Also, similar designs will be utilized for wells in alluvium or tailings. Casing and screens constructed of slip-flush joint or threaded flush joint PVC material are recommended. These casing joints have no protruding belled-ends as do standard casing material which can cause bridging of gravel/sand pack, or bentonite seal materials, resulting in poor and inadequate construction.

Concrete surface seals and locking steel covers (Figure 4-1) will be installed at all sites to complete the wells. Selected wells will require locking covers sufficient in size to house continuous water level recorders. These housingings can be constructed of paired 30inch and 36-inch corregated steel culverts and covered with a locking steel lid. Filling of the annulus between the two culverts with sand should be sufficient to protect valuable recording equipment from vandalism.

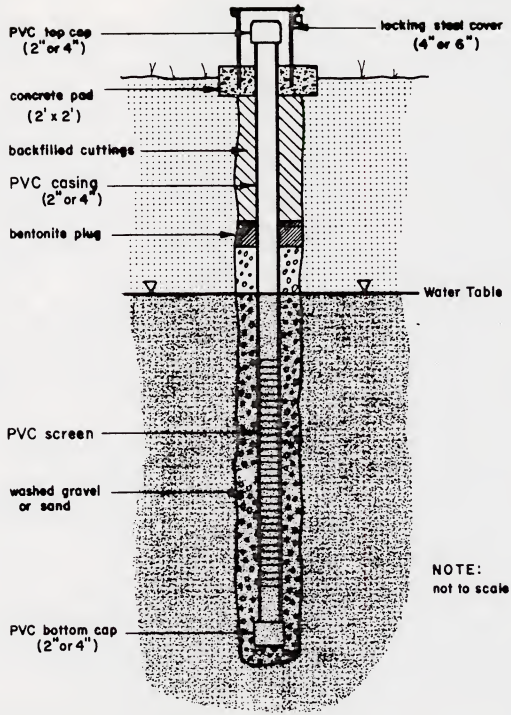


FIGURE 4-1 --GENERALIZED SCHEMATIC OF MONITORING WELL CONSTRUCTION DETAILS

Several borehole drilling methods are applicable for this study. Drilling methods most applicable are air rotary, power-augering, or hand-augering. Selection of the appropriate drilling method will be determined by site accessibility, material to be drilled, and anticipated well depth.

Top-drive air rotary will be used for most wells (both 4-inch diameter and 2-inch diameter) to be installed. The top-drive air rotary drilling method offers several advantages; foremost is its versatility. This type of drill rig has sufficient pull-down weight to drill through coarse-grained material, such as cobbles and boulders that might be encountered. Furthermore, the drill rig has the ability to drive steel casing while drilling, thus maintaining borehole stability without the need for drilling muds. Also, by driving casing, the pull-back method of screen and casing emplacement can be utilized. The pull-back method allows for gravel/sand pack and bentonite seal material to be placed in the annulus between the outer steel casing and inner PVC. The possibility of bridging is thus minimized.

Power or hand-auger of 6-inch diameter boreholes might also be used for shallow (less than 10 feet) well installations when restricted solely to the soft tailings material. The obvious advantage of these methods is cost. They should, therefore, be considered when drilling conditions permit.

All well installations will be documented by use of a drill hole log. This log should detail both the well construction details and lithologic characteristics of the material drilled. An example of a drill hole log is presented in Figure 4-2.

4.4.5.2 Well Development

Well development is the process of "cleaning out" a newly installed well. Development is conducted to remove drilling debris and fluids from the well and surrounding material. Proper well development should also remove the very-fine grained particles from the gravel/sand pack, thus allowing only filtered, sediment-free water into the well.

Several common methods are used to develop wells. These include surging with compressed air or a surge block, bailing, or over pumping. An example of a well development field form is shown in Figure 4-3.

4.4.5.3 Well Testing

Well testing should be conducted on selected wells following installation and development. The testing is conducted for the purpose of determining the geohydraulic parameters of transmissivity, hydraulic conductivity, and storativity or specific yield, for both alluvium and tailings materials. The degree of properties such as heterogeneity, anisotropy and leakage should also be determined

TEST HOLE LOG

STILLER AND ASSOCIATES
CONSULTING HYDROLOGISTS GEOLOGISTS ENGINEERS

State:_____ County:_____ Project:_____ Hole Name or Number:_____

Legal Location: T____R____Sec.____Tract____ Descriptive Location:_____

Recorded by:_____ Date Hole Started:_____ Date Hole Completed:_____ Driller:_____ Drilling Company:_____

Drill Method:_____ Drilling Fluids Used:_____ Pilot Hole Diameter:_____ Reamed Hole Diameter:_____

Total Depth Drilled:_____ Total Depth Reamed:_____ Total Depth Cased Below G.S.:_____ Diameter and Type of Casing:_____

Weight or Gage of Casing:_____ Interval Perforated or Screened Below G.S.:_____ Target Aquifer:_____ Packer Type and Depth Below G.S.:_____

	YES	NO
Well Developed?	____	____
Well Test Pumped?	____	____
Water Samples Taken?	____	____
Material Samples Taken?	____	____
E - Logs?	____	____

Static Water Level:_____ Date:_____

Method Perforated or Screened:

____ No casing in hole.
____ Open bottom only.
____ Slotted with Mill's Knife.
____ Slotted with a torch.
____ Screened by pulling casing.
____ Saw cut
____ Other (specify)_____

Measuring Point Description/Elevation:_____ MP Height Above (+) or Below G.S.:_____

Well Annulus Completion Description:_____

Remarks:_____

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling

WELL DEVELOPMENT LOG Well No._____

WELL DATA

PROJECT: Name_____State_____County_____

Location: T____R_____Sec._____Tract_____

Well Location (Narrative Desc.)_____

_____

_____

Well Depth (Ft.)_____Diameter (In.)_____Perf. Interval _____

Static Water Level_____Above/Below MP_____MP Desc._____ Meas. Date/Time_____

Aquifer_____

_____

DEVELOPMENT DATA

Date _____ Time Started_____ Time Finished _____ Total Development Time _____

Est. Yield at Start_____Est. Yield at End_____

Equipment: Bailer Sand Pump Compressor Surge Block Drilling _____(Other-Specify)

Desc. of Equipment_____

Dev. Additives Used_____

Desc. of Packer & Surface Seals_____

Water Color & Turbidity: At Start_____At End_____

Static Water Level After Development: Time After Dev. Ended_ ___SWL_____Trend_____

Operator_____

REMARKS:_____

_____

_____

FIGURE 4-3 --WELL DEVELOPMENT LOG

where possible. All well test data should be recorded on a form such as Figure 4-4.

Aquifer Tests

Constant discharge aquifer tests are recommended of the alluvial wells located at the detailed tailings monitoring site. Constant discharge aquifer tests should also be considered for the wells located proximal to Silver Bow Creek.

Aquifer testing of the alluvial well at the detailed monitoring site should provide comprehensive, definitive data regarding hydrogeologic conditions at the site. Water level monitoring in the pumping well and six observation wells during testing should provide transmissivity, storage, leakage from tailings to alluvium, and other related parameters. The aquifer tests should be 24 hours or greater in duration. Water levels should also be monitored for recovery following the test.

Aquifer tests of the other well installations may be conducted with or without observation wells. These should be of duration greater than four hours. Aquifer test data should be analyzed using current methologies such as Neuman (1975), or Newman and Witherspoon (1969a, 1969b).

AQUIFER TEST DATA

STILLER AND ASSOCIATES
CONSULTING HYDROLOGISTS GEOLOGISTS ENGINEERS

WELL OBSERVED _____
(Also Reported on This Form)
WELL TESTED _____
TEST DATE _____

Project _____ Personnel _____

WELL DESCRIPTION

State _____ County _____ Location: T _____ R _____ Sec. _____ Tract _____

Borehole Diam.(in) _____ Well Diam.(in) _____ Well Depth(ft) _____ Perforated Zone(s)(ft) _____

Desc. of MP _____ Stick-up(ft) _____ SWL below MP(ft) _____ SWL below GS(ft) _____

Aquifer Name _____ Aquifer Description _____
(Lithology, Thickness, Depth to Top)

TEST DESCRIPTION

Test Type: (Circle One)
1. Pumping Well Drawdown
2. Observation Well Drawdown
3. Pumping Well Recovery
4. Observation Well Recovery
5. Bailer Recovery
6. Slug Injection or Removal
7. Hvorslev Test
8. Other (Specify) _____

Distance of Observation Well from Pumping Well(ft) _____ Pump hp. & type _____ Pump Depth(ft) _____

Water Quality Sample Taken? yes no Specific Conductance (umhos/cm @ 25°C) _____ Temp(°C) _____ Time _____

Avg. Discharge(gpm) _____ Test Duration(min) _____ Max WL Change(ft) _____ Transmissivity (gpd/ft) _____

Storetivity _____ Hydraulic Conductivity(gpd/ft²) _____ Specific Capacity(gpm/ft of drawdown) _____

REMARKS _____

Date & hour	Time							

FIGURE 4-4 --AQUIFER TEST DATA

Slug Tests

Slug tests are conducted by instantaneously removing or adding a known volume of water (or solid) from or to a well and monitoring the response in water level. The tests designed for a single wells, are relatively quick and inexpensive methods of determining hydraulic conductivity. Slug tests should be conducted in wells that are not pump tested. The test data should be analyzed by methods such as Cooper and others (1967) or Cedegren (1977).

4.4.5.4 Water Level Monitoring

Water level monitoring is planned for selected wells. Water level monitoring is of two types: periodic and continuous.

Periodic Measurements

Periodic water level measurements are instantaneous measurements of the depth (from the measuring point down) to standing water. The measurements are made at specified time intervals (e.g. monthly). The measurements are made with steel tape or, more currently, with electric probes that are calibrated, generally to 0.1 foot accuracy.

Measurements made in wells that are used for no other purpose than monitoring are relatively simple, because no interference of the water level is expected. Measurements made in wells that are equipped with pumps and used for other purposes are often difficult.

Well owners should always be contacted prior to monitoring so that the respective wells can be shut down and allowed to recover to static levels.

An additional precaution for any water level monitoring program is to beware of inherent errors introduced by using different and uncalibrated tapes. Two or three tapes, pre-calibrated to each other, should always be available in the event that one is destroyed. These tapes should be dedicated strictly for monitoring and not used for other purposes where damage may occur, such as aquifer testing.

Continuous Recording

Continuous water level measurements are accomplished by use of equipment such as the Leupold-Stevens Model F-1 recorder. These devices contain battery operated clocks that drive an ink pen across a calibrated chart. The chart is taped to a drum that is attached to a float suspended in the well. Thus, as the pen moves across the chart, minor fluctuations in water level in the well are continuously recorded. Thirty-two day clocks are adequate for ground water monitoring. Charts must be changed and the equipment serviced in accordance with manufacturers' recommendations once every month.

4.4.5.5 Tailings Vadose-Zone Monitoring

Detailed monitoring will be conducted at one site, as identified in Section 2.1.3.4 to detect variation in moisture potential, moisture content, and pore-water chemistry within the unsaturated zone above the water table in floodplain tailings deposits. The monitoring system will be installed to investigate the effects of water movement through the unsaturated zone on subjacent ground water quality. Three specific instruments will be utilized: tensiometers, soil moisture blocks (gypsum block), and suction lysimeters.

Four nested tensiometers will be installed at the site to obtain measurements of soil moisture potential. With proper calibration, the measured potential can be converted to soil moisture content (Morrison 1983). With the installation of several tensiometers at various depths, a hydraulic gradient can be established to determine the flow direction of water through the unsaturated zone. General installation of a tensiometer involves augering of a small diameter hole, insertion of the tensiometer, and backfilling of the augered material mixed into a slurry. The hole is then sealed with bentonite or grout.

Soil moisture blocks will be used to measure soil moisture directly and to calibrate the tensiometer. Soil moisture blocks are sensors, usually made of gypsum, which measure soil moisture as a function of the resistence between two electrodes embedded in the porous material. Moisture blocks can be installed horizontally in hand

augered boreholes. For individual placement, a slurry of 200 mesh sand is poured into the bottom of the hole, and the block buried in it. Augered material is then backfilled. This procedure is repeated at desired depths for multiple installations.

Four vacuum pressure lysimeter will be installed at the site for the purpose of sampling pore water quality at selected depths within the unsaturated tailings. A lysimeter is a sampling device, fitted with a hydrophilic filter material, which is connected to the surface via vacuum tubing. When a vacuum is exerted on the lysimeter, pore water is induced to flow toward and into the vessel and then to the surface. Installation, as with tensiometers, is generally by insertion in a borehole and then back filled. Numerous lysimeter designs are available, and installation and operation are dependent on manufacturers' recommendations and requirements. Utilization of the vadose-zone monitoring system should follow recommendations in Wilson (1980) and Morrison (1983).

4.4.6 Laboratory Analysis for Algal Investigation

Chlorophyll

- Standard Methods 100 2 G. 3.

- Procedure
  - Pond: Filter wash sample then process as follows for stream.
  - Stream: Freeze algae three to four weeks, filter through glass fiber filter, pre-weighed. Extract chlorophyll with five to 10 mls 90% acetone for 30 days, centrifuge at high speed for 10 minutes. Measure extraction about three wavelengths spectrophotometer.

Biomass

- Standard Methods 100 3 C. 4.

- Procedure: Ash Free Dry Weight
  Filter algae sample through galss fiber filter, pre-weighed. Dry at 105°C for 24 hours to constant weight, then ash at 600°C for 1 hour. Cool and weigh.

Metal Absorption

- Procedure

Wash glass fiber with .1$NHNO_3$, dry filter to constant weight. Filter sample and discard filtrate. Wash filter with known volume 1$NHNO_3$ and analyze filtrate for As, Cd, Cu, Pb, Hg, Zn, and Fe.

4.4.7 Fish Sampling Methods for the Warm Springs Ponds Fish Tissue Study

To collect brown trout (Salmo trutta) in Pond No. 2 a shocking technique from a boat is recommended. Once a fish is collected it will be weighed, measured, a scale taken for age classification, put into a plastic Whirlpak bag, and placed on ice. The Whirlpak bag will be properly labeled using a label similar to the one shown in Table 4-3. Following the days collection, the fish will be dissected for muscle tissue. Each tissue will be placed in a separate Whirlpak, labeled and frozen. Dissection will take place indoors utilizing plastic or Teflon® coated tools and trays. A Fish Collection Logbook will be kept to record pertinent field data. A sample page is shown in Table 4-4.

TABLE 4-3 —SAMPLE LABELS

Waterfowl Carcass Label

Field ID_____

Collector_____ Date___/___/___

Location: Pond 2_____ Pond 3_____ Clark Fork River_____

Control_____ Other_____

Species_____ Age_____

Fish and Wildlife Tissue Label

Field ID_____ Tissue_____

Sample Bank No._____ _____

Special Instruction_____

Macroinvertebrate Sample Label

Field ID_____ Method_____

Collector_____ _____ Date___/___/___

Location: Pond 2_____ Pond 3_____ Clark Fork River_____

Control_____ Other_____

Picker_____ Date___/___/___

Sample Bank No._____

TABLE 4-3 --SAMPLE LABELS (Continued)

Macrophyte Sample Label

Field ID_____ Method_____

Collector_____ Date___/___/___

Location: Pond 2_____ Pond 3_____ Clark Fork River_____

Control_____ Other_____

Species _____ Voucher: Yes/No

Sample Bank No._____

Fish Sample Label

Field ID_____ Method_____

Collector_____ Date___/___/___

Location: Pond 2_____ Pond 3_____ Clark Fork River_____

Control_____ Other_____

Species _____

TABLE 4-4 --SAMPLE PAGE FROM THE WATERFOWL AND FISH COLLECTION LOGBOOK

Field ID_____ Date___/___/____

Collector_____ Location_____

Species_____ Age_____

Tissue_____ Sample Bank No._____

Tissue_____ Sample Bank No._____

Tissue_____ Sample Bank No._____

Tissue_____ Sample Bank No._____

Tissue_____ Sample Bank No._____

Document Control No._____ on ___/___/____

Sample Bank Received _____ on _____
Name Date

4.4.8 Collection Methods for Warm Springs Ponds Waterfowl Investigation

Waterfowl required for this investigation shall be collected utilizing a shotgun and steel shot. Appropriate waterfowl hunting techniques shall be used such as a dog for retrieval, decoys, etc. A collection permit will be required from the MDFWP to collect waterfowl out of season. Additionally, permission should be requested from the owner of the Warm Springs Ponds, the Anaconda Minerals Company, Butte, Montana.

Upon retrieval of the waterfowl carcass, it will be shaken to remove as much water as possible, placed in a large labeled, plastic (Whirlpak) bag, and stored in a cooler on ice. At the end of the collection day, the carcasses will be dissected on plastic trays using Teflon® coated dissecting tools to remove the tissue of interest. All tools will be washed with dilute HNO_3, then rinsed three times with reagent grade deionized water between tissues and again between carcasses. All trays will be washed with dilute HNO_3 then rinsed three times with reagent grade deionized water between carcasses. Each tissue will be placed in a separate, labeled Whirlpak bag and frozen. Table 4-3 shows an example of carcass and tissue labels.

A log book of samples collected will be kept. Table 4-4 shows an example page from the log book. In addition to the sample labels and sample log book, the chain-of-custody forms found in the QA/QC Plan will be utilized.

4.4.9 Tissue Preparation Methods

The tissue samples will be allowed to thaw. Then, the whole tissue from each Whirlpak bag will be homogenized using a stainless steel laboratory tissue homogenizer capable of handling tissue samples of such a large size. Following homogenation, a sample aliquot of approximately 1 gram will be removed from the homogenation vessel and placed into a pre-weighed digestion vessel.

The homogenation tools and vessels will be cleaned between each sample by washing first in a strong detergent, rinsing with tap water, washing with strong HNO_3, and rinsing three times with reagent grade deionized water.

The sample aliquot and digestion vessel will be weighed to obtain the wet weight of the tissue to be digested. The sealed tube digestion technique as described by Van Meter (1974) will be used to obtain an aqueous solution for trace element analysis; or a hot nitric/sulfuric acid digest in a flask will be used.

4.4.10 Laboratory Analysis Methods for Warm Springs Ponds Waterfowl Investigation

Analysis of aquous solutions prepared as described in 4.4.9 for As, Cd, Cu, Pb, Hg, and Zn will be performed as described in the QA/QC Plan. If meeting the aquous solution QA/QC objectives does not give appropriate results then the digestion will be repeated with additional tissue as appropriate with follow-up analysis.

4.4.11 Data Summaries and Statistics for Warm Springs Ponds Waterfowl Investigtions

The basic tool for use in comparing the levels of contaminants found in the various tissues recommended for testing will be an analysis of variance (ANOVA) within each group. An ANOVA will be performed to evaluate the effects of location, time, age (if appropriate), species (if appropriate), and tissues. Means, standard deviations, and correlation coefficients will also be used to describe the location, distribution, and possible relationships of the data.

4.4.12 Soil Sample Acquisition Protocols

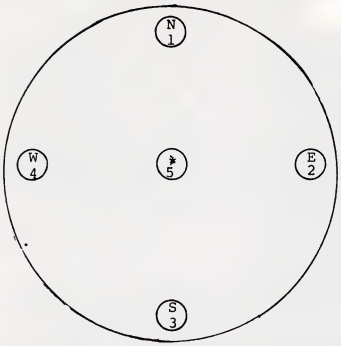
4.4.12.1 Location

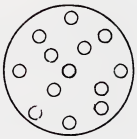
The identification and description of pertinent one-tenth (0.1) acre sample plots is discussed in subsection 2.2.3.2. Once each plot has been documented appropriately, a composite soil sample weighing approximately 1000 grams (fresh weight) per depth interval will be obtained via subsampling of material at each of the four (or five) subplots. The layout of each circular plot (and subplots) is shown in Figure 4-5, Part A.

Some of the designated soil sampling locations may not be sufficiently large to collect soils around the circumference of the 0.1 acre plot. If this case arises, the reduction of the diameter of the circle by three- (3) foot increments to a minimum plot diameter of approximately 36 feet will be acceptable. If a circular plot is not feasible, then a rectangular plot having a width of 5 feet and length of 15 feet will be chosen. In such cases, subsampling will occur as shown in Part B of Figure 4-5. The rectangular configuration will be commonly used when sampling in, or peripheral to, the cropland (sampling) sites. These subsamples will then be composited in the same manner as described for the circular plot.

The sample location types, depth intervals to be sampled, and probable means of acquiring the samples (per site) are summarized in Table 4-5, Part A. For general reference the estimated cummulative

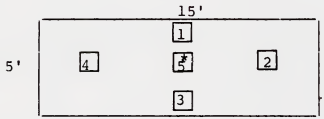
PART A. CIRCULAR 0.1-ACRE PLOT, WITH FOUR SUBPLOTS (EACH 0.92 SQUARE-FEET)

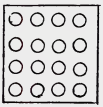




Subplot with 13 core holes (an arbitrary number) resulting from manual coring. When the Giddings' sampler is used, the core will be extracted from the center of each subplot.

PART B. RECTANGULAR PLOT (75 SQUARE-FEET), WITH FOUR SUBPLOTS (EACH 1.0 SQUARE-FEET)





Subplot with 16 core holes (an arbitrary number) resulting from manual coring. When the Giddings' sampler is used, the core will be extracted from the center of each subplot.

* Equals Plot Center

FIGURE 4-5 PROPOSED 0.1 ACRE SOIL/CROPLAND SAMPLING PLOT ARRANGEMENTS

TABLE 4-5 --OVERVIEW OF SAMPLE LOCATION TYPES, DEPTH INTERVALS TO BE SAMPLED, PROBABLE MEANS OF SAMPLE ACQUISITION, AND ESTIMATED SAMPLE WEIGHTS

PART A. SAMPLE LOCATION TYPES, DEPTH INTERVALS, AND SAMPLING PROCEDURE

Location Type	Depth Intervals (inches)	Probable Means of Sampling
Native, uncultivated soils.	0-4, 4-12, 12-28	Giddings' hydraulic, rotary-type soil coring machine.
Native, cultivated soils.	0-4, 4-12, 12-28	Giddings' sampling machine where possible; otherwise Oakfield (manual) coring device, or equivalent.
Especially gravelly or cobbly floodplain soils.	0-4, 4-12	Oakfield (manual) coring device or equivalent and sharpshooter-type spade, or equivalent.

PART B. ESTIMATED WEIGHTS OF SAMPLES ACQUIRED PER LOCATION AND DEPTH INTERVAL

Location Type	Weight (grams)[a] 0-4 in.[b]	12-24 in.	12-28 in.
Native, uncultivated soils	1003	2006	4013
Native, cultivated soils	1070	2140	4280
Especially gravelly or cobbly floodplain soils.	1070	2140	—

Notes:

a) Assumes use of a 1-5/8" i.d. soil probe (tube) and following fresh weights for the soil types: 1.5, 1.6, and 1.6 gm/cm^3 for uncultivated, cultivated, and "lithic" soils, respectively.

b) In order to acquire sufficient sample weight for compositing purposes, a fifth core will be acquired to a depth of 4 inches only. This fifth core will add 250 to 270 more grams to the bulk sample (depending upon location type) for compositing purposes.

weights per site type-depth interval are shown in Part B of this same table. At least 1 kg. of composited sample will be acquired per site-depth increment. Thus, this table also provides the rationale for extracting a fifth core to meet requirements for the 0-4 inch sample interval.

4.4.12.2 Sampling Procedures

Table 4-5, Part A indicates that soil sampling will use either hand-held equipment or an hydraulic, rotary-type, coring machine. Where site conditions (e.g., access) allows, the mechanized approach will be used, given its greater speed of sample acquisition. However, where access to the Giddings sampler is denied, Oakfield-type tube samplers and sharpshooter-type spades will be substituted. These two general approaches to gathering of depth-integrated composite samples are discussed below.

Sample Acquisition by Hand-Held Tube Sampler or Shovel

A stainless steel tube sampler (soil probe) with footstep, having an inside diameter of three-fourth inch and cut-out length of at least 12 inches is recommended. An alternative to the above probe is the Oakfield Model KB sampler, wherein each subsample (per site) is collected individually in plastic bags attached to the sampler. Initially, at each sodless coring location the vegetation (if present) will be removed to ground surface using a stainless steel knife. The probe is then driven vertically into the soil to a

depth of 12 inches, as marked on the outside surface of the corer. In this fashion, the 0-4 and 4-12 inch depth intervals are sampled simultaneously. The surface (0-4 in.) sample shall consist solely of mineral soil; any surface litter, vegetative sod, etc. will be removed via use of a sharp knife or scalpel. Soil sampling of sites in sod will be accomplished similarly to that for fields not in sod except that the 0-1 inch increment will be comprised primarily of organic material (plants and their roots) with soil particles attached. The 0-1 inch depth increment will be excavated then shaken vigorously over a clean piece of 6 mil plastic measuring ~4 ft^2, (Dollhopf et al. 1984, p. 26). This procedure will separate the soil from the roots. The resulting soil will be placed in the pertinent collection bowl, while the organic portion (i.e., remaining plants with roots) will be discarded. Successive soil sampling will then proceed by depth increment as described below.

In case of reduction in core length due to compaction, the following two-step procedure shall be observed. First, the percent reduction in total core length will be entered onto the field sheet. Secondly, the sample interval lengths will be "adjusted" by this percentage. For example, the upper 3-3/4 inch of compressed core may be taken to represent the upper 4 inches of "natural," uncompressed core. Soil cores noted to be less than 75 percent of their "normal" (uncompressed) length will be discarded, and a new core will be substituted for it. The litter-free surface core material is placed in a one gallon stainless steel bowl or bucket. The subsurface (4-12 in.) material (per core) is placed in a second (one

gallon) stainless steel container. The above process is repeated at each of the five subplots until at least 1200 grams of soil (per depth interval) has been acquired.

A stainless steel garden-type trowel will be used to disaggregate and blend the materials contained in the surface sample container. The mixing-blending process is continued until the crew leader judges the material to have uniform color, texture, etc. The trowel is then used to scoop out soil which is passed through a one-quarter inch mesh stainless steel screen; the screened material is collected in a second stainless steel bowl. Thus rock fragments, plant roots, etc., whose diameter exceeds the given mesh size will not be included in the composite sample. Such "large" materials are extraneous to the sampling process, as only the soil materials passing 2 mm mesh (screen size) will be utilized in the laboratory. The trowel is then used to scoop out--from the second bowl--1.0 to 1.5 kilograms (kg) of composite sample, which is placed incrementally into the appropriately labeled bag. The filling process can be monitored via use of a spring-type tubular weighing scale or portable balance. The soil samples are to be contained in sealable polyethylene containers of at least 36 ounce (~1022 gm) capacity. The Whirl-Pak® 4-1/2" x 15" sterile sample bags are recommended for non-gravelly samples while 10" x 18", 4 mil thick bags are recommended for gravelly soils. Precleaning of the bags will not be necessary. The sample bags should be stored and kept in a closed container

(until used) so as to minimize the chances of atmospheric (particulate) contamination. Any surface materials remaining in the collection bowl following acquisition of the composite sample are scattered throughout the plot. The above disaggregation-blending process is then repeated for the "subsurface sample" bowl, thus resulting in a 4-12 inch (depth) composite sample.

Approximately three soil pits will be excavated by shovel within each plot. These pits will allow sampling of the 12- to 28-inch soil materials. The depth interval may not be satisfied if a paralithic or lithic contact is encountered prior to reaching 28 inches. In such cases, this occurrence will be noted on the field sheet. At each selected site, L-shaped pits will be dug with a clean, sharp-edged "sharp shooter" type spade. One pit will be excavated to a depth of 28 inches (or upon reaching the paralithic contact) at each of the three previously utilized subsampling sites, as selected by the field crew leader. A composite sample will then be acquired in the same manner as discussed above. A fourth bowl will not be necessary, as one of the three previously used bowels can be cleaned and then utilized here.

All materials coming into contact with the soil samples will be washed in laboratory grade detergent (e.g., 0.1 percent phosphorus/metal-free solution of Alconox®), doubled rinsed with clean tap water and then with D.I. water. The rinsed equipment is then wiped dry with a disposable Kimwipe® towel. This procedure will be utilized between subplots (within a given plot) and also prior to

proceeding to the next plot. All soil samples will be stored in a cooler, which in turn is kept locked in the field vehicle until custody of the samples is transferred to the sample bank at the end of each sampling day (see Section 5.3 in the Quality Assurance Plan).

4.4.12.3 Sample Acquisition by Use of the Giddings® Soil Coring Machine

A Giddings Machine Company (Fort Collins, Colorado) hydraulic, rotary-type, soil coring and sampling machine will be used whenever site conditions allow. The truck- or trailer-mounted unit may be self-powered or be operated from the vehicle power-take-off. Soil coring tubes used will be 2" x 48" (diameter x length) and possess a series of 5/8" slots to permit observation of the sample. Tube bits (2 in.) will be of three general types: standard taper, saw-tooth, or heavy duty quick relief. The sawtooth bits yield best results when sampling hard clays or sandstone, while the heavy duty bits are recommended in rocky conditions and for heavy, wet clays. The tube-bit combination is attached via an adapter (and adapter pin) to the kelly bar; the bar is in turn fitted into the (overall) mast assembly. All machinery components will be assembled and operated in accordance with the manufacturer's instructions. Furthermore, the tube, bit, and adapter assembly will be made out of stainless steel (rather than the commonly used molychrome alloy).

At each subsampling location (per plot, Figure 4-5), the sampling assembly will be driven approximately 30 inches into the earth; the penetration depth will be measured to the nearest one-quarter inch. The rotary head is then activated, causing the soil plug to be sheared off at the measured depth. The tube is then withdrawn from the hole and disconnected from the adapter, thus allowing removal of the sample from the top of the tube. The tube is slowly inclined with the open top facing down towards a clean polyethylene sheet placed on the ground; gentle tapping of the sides of the barrel may be needed to hasten soil core removal. The core is then measured and compaction effects are adjusted for, as discussed previously.

The core is sliced via use of a sharp stainless steel knife or scalpel into the 0-4, 4-12, and 12-28 inch intervals, with each increment being placed in a separate stainless steel mixing bowl. The Giddings machine is then set up sequentially over the second through fifth subplots, thus gathering three depth-integrated samples at each subplot. Once the coring per site is completed, three composite samples (one per depth increment-site) are prepared as discussed previously. The soil coring assembly will be scrubbed (inside and out) using the hydraulic rotary tube brush, then further decontaminated with soapy water, tap water and D.I. water rinses, and finally dried with a Kimwipe® towel. This process will be repeated between subplot sampling (at a particular site), and especially prior to proceeding to the next sampling site.

4.4.12.4 Sample Labeling

The sample collection tags will be numbered serially, preferably starting with a project identifier code (e.g., SBC represents "Silver Bow Creek Superfund Project"). The suggested format is shown in Figure 4-6. The tags will be preprinted to ensure that the required information is provided on each tag. Each collected sample shall have a completely filled-in sample tag securely attached to it. Samples collected for splits shall be identified in the remarks section of the tag.

The person who physically collects the sample is the sampler and signs the sample tag. The sampler initiates the custody record for transfer of samples to the sample bank.

4.4.12.5 Preanalytical Sample Handling and Storage

The original (field) sample collection tag number is recorded in the sample bank's master log and the tag itself is stored in the document file at the Sample Bank (see Section 4.2.2 in the Quality Assurance Plan). For crop samples only leave the sample collection tag on the sample container. Traceability of samples from collection location to laboratory analysis is required; thus, cross-indexing of all sample collection tag numbers, and corresponding sample bank and analytical tag numbers must be made in the master log book, (Brown et al. 1983).

PROJECT: Silver Bow Creek

Date:

SAMPLE LOCATION:

Military Time:

Samplers 1) _____

2) _____

Split 1 2 3 4 5

a b c

SAMPLE TYPE

SOIL	CROP	HAIR/BLOOD
Trace Metals:*	Trace Metals:*	Total As
Total	Total	Total Cd
Extractable	Extractable	Total Cu
pH	P	Total Pb
SAR	K	Total Zn
CEC	S	Other Elements
EC	N	Mo
NO_3	Others:	____
NH_4	____	____
P	____	____
K	____	____
B	____	____
Se	____	____
Texture	____	Animal Identification No:_____
Others:	____	
____	____	
____	____	
____	____	

Size Fraction:
> 2 mm
< 2 mm

Remarks:

* As, Cd, Co, Cu, Mn, Mo, Pb, Zn (Circle as Appropriate)

Source: Adapted from Figure 23, In Dollhopf et al. 1984 (p. 60p).

FIGURE 4-6 --RECOMMENDED SAMPLING TAG FOR AGRICULTURAL MATERIALS

The Sample Bank will be responsible for generating homogeneous soil samples. The drying, grinding, and sieving processes are discussed in Appendix 4.4.13. At the time of analysis, the Sample Bank issues a subsample of the appropriately prepared sample to the particular laboratory personnel in need of it. The unused (unanalyzed) materials shall be returned to the Sample Bank.

Those soil samples identified as being trace element (triplicate) splits on the sample collection tag will be dried and mixed and then split into three separate samples for analysis. One of the split samples will be shipped to the referee analytical laboratory. The identification of these split samples must be documented in the master log. Crop and livestock samples identified as being duplicates on the sample collection tag will also be shipped to the same analytical laboratory.

The equipment used for drying, sieving, and mixing the soil must be decontaminated after each sample processed and at the end of each day. Between samples, all equipment will be blown clean with compressed air to remove contamination (e.g., materials caught in the screen, along edges of collection pans, etc.). Following this procedure, each potentially contaminated component of the drying, sieving, mixing, and grinding equipment will be vacuumed and then wiped down using a sponge moistened with hot Alconox (0.01 percent w/v) solution. The equipment will then be rinsed with D.I. water, and wiped dry with a disposable Kimwipe® towel. The metal-free

laboratory detergent and laboratory brushes or Kimwipes will be used also in the decontamination procedure at the end of each sample preparation day.

4.4.13 Soil Analytical (Laboratory) Methods

4.4.13.1 Sample Preparation

The following procedures will be applied to all soil materials chemically analyzed for the designated trace element suite. The preparatory methods implemented prior to other analytical procedures are given where applicable. Initially, the raw samples (contained in plastic sacks) are received from the field crew leader by sample bank personnel. The field-composited sample for a given depth increment and site is then processed as shown in Figure 4-7.

4.4.13.2 Plant-Available Trace Metals Extraction via Diethylene Triamine Pentaacetic Acid (DTPA) Solution

The preparation and analysis of "plant-available" trace ion levels in non-acidic substrates (pH $\geq$ 7) will be accomplished in the manner described by Soltanpour and Schwab (1977).

4.4.13.3 Total Trace Element Analysis

The selected trace elements may be determined via use of energy dispersive X-ray fluorescence spectrometry (EDXRF). The method detection limits (mdls) for this method may be higher than those resulting from AAS or ICP methods (i.e., ppm mdls vs. fractional ppm mdls, respectively). However, the XRF technique involves a relatively simple sample preparation step and avoids wet ashing

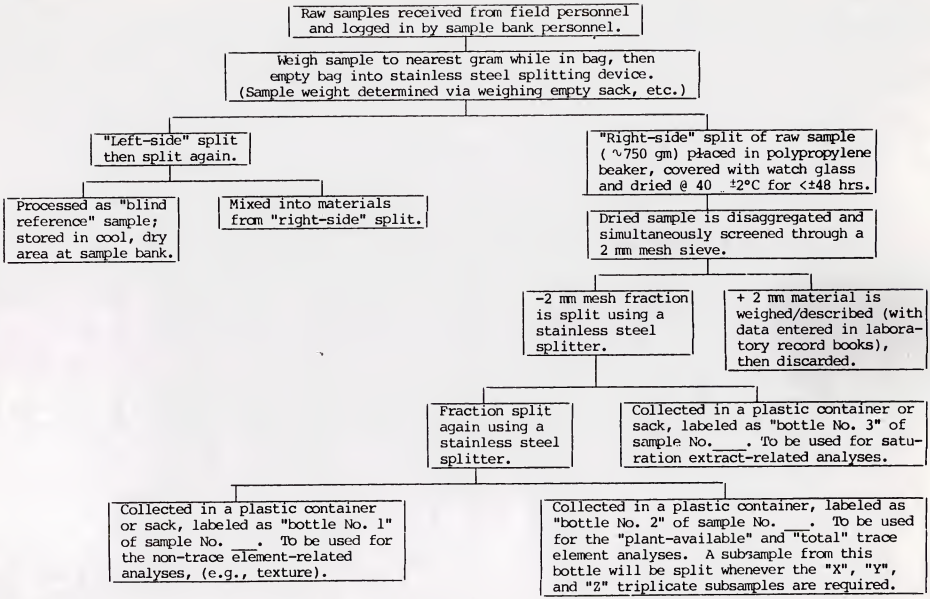

Raw samples received from field personnel and logged in by sample bank personnel.
Weigh sample to nearest gram while in bag, then empty bag into stainless steel splitting device. (Sample weight determined via weighing empty sack, etc.)
"Left-side" split then split again.
"Right-side" split of raw sample (∿750 gm) placed in polypropylene beaker, covered with watch glass and dried @ 40 ±2°C for <±48 hrs.
Processed as "blind reference" sample; stored in cool, dry area at sample bank.
Mixed into materials from "right-side" split.
Dried sample is disaggregated and simultaneously screened through a 2 mm mesh sieve.
-2 mm mesh fraction is split using a stainless steel splitter.
+ 2 mm material is weighed/described (with data entered in laboratory record books), then discarded.
Fraction split again using a stainless steel splitter.
Collected in a plastic container or sack, labeled as "bottle No. 3" of sample No.____. To be used for saturation extract-related analyses.
Collected in a plastic container or sack, labeled as "bottle No. 1" of sample No. ___. To be used for the non-trace element-related analyses, (e.g., texture).
Collected in a plastic container, labeled as "bottle No. 2" of sample No. ___. To be used for the "plant-available" and "total" trace element analyses. A subsample from this bottle will be split whenever the "X", "Y", and "Z" triplicate subsamples are required.

FIGURE 4-7 —PREPARATION SCHEME FOR SOIL SAMPLES

(digestion). Furthermore, the non-destructive nature of the determinative step allows retention of the sample for further analysis (or re-analysis) at a later date. Technical details can be found in Appendix C-7 of U.S. EPA et al. (1983) and in A. A. Jones as cited in Page et al. (1982). With minor modifications, EDXRF is suitable for analysis of a number of major and minor elemental constituents (in soils). If EDXRF is not approved for this analysis, standard hot mineral acid digests with element detection by spectroptical methods will be used.

4.4.13.4 Analysis of Various Biological and Physiochemical Parameters Important to Evaluation of Agricultural Productivity

The analyses of irrigation water-contaminated soils for assessing reclamation potential will require knowledge of certain biological, chemical, and physical properties. The incorporation of these laboratory data with site evaluation criteria (e.g., slope gradient, aspect, rockiness) will allow a rigorous assessment of soil-water system dynamics present at the various cropland areas. The Montana Department of State Lands (MDSL) has recently authored a comprehensive analysis checklist for strip-mined land reclamation, (MDSL 1983). As these guidelines are often applicable to the present study area, those pertinent analyses recommended for implementation are presented in Table 4-6. This table should be reviewed along with the analytical flow-chart presented in Figure 4-8 to acquire an overview of the laboratory procedures to be applied to the soil samples.

TABLE 4-6.—BIOLOGICAL AND PHYSIOCHEMICAL PARAMETERS, AND THEIR RESPECTIVE ANALYTICAL METHODOLOGIES, IMPORTANT TO ASSESSING RECLAMATION POTENTIAL OF AFFECTED AGRICULTURAL (IRRIGATED) LANDS

PART A. BIOLOGICAL (BIOCHEMICAL) PARAMETER

Parameter	Recommended Method(s)
Carbon Dioxide (CO_2) Evolution	Stotzky, G. 1965. Microbial Respiration, Method 113-6, pp. 1562-1565 In C.A. Black et al. 1965.

PART B. CHEMICAL PARAMETERS

Parameter	Recommended Method(s)
Anions	
› Boron ($H_2BO_3^-$)	Hot water-soluble method described in Crock and Severson 1980. USGS Circular 841.
› Carbonate (CO_3^{-2})	Sandoval and Power 1977, Carbonate and Bicarbonate, pp. 27-28 In USDA Agriculture Handbook No. 525.
› Chloride (Cl^-)	Rhoades, J. D. 1982. Soluble Salts, extraction procedure 10-2.3, pp. 168-169; analytical step completed by potentiometric titration or direct potentiometric (i.e., specific ion electrode, SIE) method as discussed in Adriano and Doner, Bromine, Chlorine and Fluorine, Method 26-3, pp. 455-460 In A. L. Page et al. 1982. This ion can also be analyzed for by ion chromatography, (e.g., Dionex® 1979).
• Phosphate ($H_2PO_4^-/HPO_4^{-2}$)[a]	For acid soil or mill tailings-contaminated areas (pH < 7), use 0.05 N HCl + 0.025 N H_2SO_4 extractant; for "alkaline" substrates (pH ≥ 7) use 0.5 N $NaHCO_3$ extractant. See Woolson et al. 1971, plus Johnston and Barnard 1979, for methdological details. Analytical step using the spectrophotometric method presented in Olsen and Sommers 1982. Phosphorus, Method 24-3.4, pp. 413-414 In A. L. Page et al., 1982. This ion can be analyzed for by use of ion chromatography, (e.g., Dionex® 1979).

TABLE 4-6. (Continued)

PART B. CHEMICAL PARAMETERS (Continued)

Parameter	Recommended Method(s)
• Sulfate (adsorbed and soluble forms, SO_4^{-2})	Calcium phosphate monohydrate (500 ppm P) extractant technique on field-fresh samples, reduction and distillation of H_2S, followed by estimation using methylene blue. See M. A. Tabatabai, 1982. Sulfur, Method 28-3.2, pp. 520-522 In A. L. Page et al. 1982. An approximation of soluble sulfate content will be provided by ion chromatographic analysis of the saturation extract, W. A. Dick and M. A. Tabatabai 1979.
Cations (Nutrients)[b]	
• Calcium content in the saturation extract, in meq/l	Analysis by atomic absorption spectrophotometry, USDA Handbook 525, Method 2, pp. 24-25. See also J. D. Rhoades, 1982. Soluble Salts, Method 10-3.4, pp. 173-174 In A. L. Page et al. 1982.
• Magnesium - same as for calcium	Same as for calcium.
• Sodium - same as for calcium	Same as for calcium.
• Potassium - same as for calcium	Same as for calcium.
SAR (sodium adsorption ratio)	Richards, L. A. et al. 1954. USDA Handbook No. 60, pp. 26-27.
ESP (exchangeable sodium percentage). This is an alternative to SAR analysis in soils.	USDA Handbook 525, No. 6A, p. 9. (Note methods 5A and 5B, as referenced, are on pp. 7 and 8.)
Electric Conductivity (of saturation extract)	USDA 1978. Laboratory Methods Recommended for Chemical Analysis of Mined-Land Soils and Overburden in Western United States, Method 1, pp. 22-24, (Handbook 525).

TABLE 4-6. (Continued)

PART B. CHEMICAL PARAMETERS (Continued)

Parameter	Recommended Method(s)
Lime Requirement (LR)	For soils having pH values < 6, the Shoemaker-McClean-Pratt (SMP) single buffer method will be used. For substrates having pH > 6, the SMP double buffer method will be used. Technical details can be found in E. O. McClean 1982. Soil pH and Lime Requirement, Methods 12-3.4.4 (pp. 215-217) and 12-3.4.5 (pp. 218-219), respectively In A. L. Page et al. 1982. See also McClean et al. 1978.
Nitrogen	
• Ammonium Ion (NH_4^+)	Keeney and Nelson 1982. Nitrogen-Inorganic Forms, present in the ~ 2M KCl extraction procedure as Method 33-3.2, p. 649 In A. L. Page et al. 1982. The analytical step (by ammonia-specific electrode) is detailed in W. L. Banwart et al. 1972.
• Nitrate Ion (NO_3^-)	Use nitrate specific-ion electrode technique discussed in Keeney and Nelson Nitrogen-Inorganic Forms, Method 33-6.3, p. 671 in A. L. Page et al. 1982. An estimate of soluble nitrate content will be provided also by ion chromatographic analysis of the saturation extract; see Dick and Tabatabai 1979.
• Total Kjeldahl Nitrogen	See Section 4.4.17 for the proposed method. An alternative approach is presented by J. M. Bremner and C. S. Mulvaney 1982. Total Nitrogen, Method 31-3, pp. 610616 In A. L. Page et al. 1982.
Organic Carbon Content	Nelson, D. W. and L. E. Sommers 1982. Total Carbon, Organic Carbon, and Organic Matter, Method 29-3.5.2, pp. 570-571 for the proposed Walkley-Black Procedure or Method 29-3.5.3, pp. 571-573 (modified Melbius procedure) In A. L. Page et al. 1982.
Organic Matter Content	This parameter will be estimated by multiplying the (above) organic carbon content value (per sample) by 2.0. The rationale for use of this factor is discussed on p. 574 In A. L. Page et al. 1982.

TABLE 4-6. (Continued)

PART B. CHEMICAL PARAMETERS (Continued)

Parameter	Recommended Method(s)
pH (determination using saturated paste)	USDA Handbook 60, Method 21a, p. 102.
Saturation Extract and Saturation Percentage Determination	USDA Handbook 60, Methods 2 and 3a, pp. 84 and 88, and Method 27a, p. 107.
Sulfide Ion (Pyritic Sulfur)	Determined most accurately using the method by D. L. Sorenson et al. 1979. An alternative, albeit less accurate, method for the determination of HNO_3-extractable sulfur (i.e., largely pyritic forms) is found in Method 3.2.6, pp. 60-62, In A. A. Sobeck et al. 1978. The resulting data can be used in estimating total lime requirement in soils contaminated by mill tailings, etc., as discussed in D. L. Sorensen et al. 1980.
Total Sulfur	Determined via X-ray fluorescence, as discussed in G. Brown and R. Kanaris-Sotiriou 1969. An alternative, abeit less accurate, method would use the Leco® induction furnace and sulfur analyzer; technical details can be found in the Leco® instruction manual (1976, 1978).
"Toxic/Heavy Metals," Group No. 1[c] • As • Cd • Cu • Pb • Zn	Lindsay, W. L. and W. A. Norvell 1978.
"Toxic/Heavy Metals," Group No. 2[c] • Al[d] • B • Hg • Mo • Se • Tl	Total and "plant-available" estimates per element will be determined via energy dispersive X-ray fluorescence plus atomic absorption spectroscopic and/or inductively coupled argon plasma emission spectrometric methods, respectively.

PART C. PHYSICAL PARAMETERS

Parameter	Recommended Method(s)
Soil Textural Analyses	
• Particle size analysis. Report as % sand, % silt, and % clay, as well as the USDA textural classification.	Day, P. R. 1965. Particle Fractionation and Particle-Size Analysis, Method 43-5, pp. 562-566 In C. A. Black et al. 1965.
• Percent very fine sand (i.e., 0.05-0.10mm) on 0-4 and 4-12 inch (depth increment) samples. Can be used in calculating the K factor for later insertion into the universal soil loss equation.	Day, P. R. 1965. Particle Fractionation and Particle-Size Analysis, Method 43-4, pp. 554-556 In C. A. Black et al. 1965.

Notes:

a) These extraction/analytical methodologies are suitable for soils of varying pH. However, many of the specific methods utilize costly reagents and also are time consuming. MultiTech recommends the utilization of ion chromatography (IC) for the determinative step wherever possible. Such approach was used to reduce per-sample analysis cost estimates.

b) In order to reduce per-sample analysis costs, MultiTech recommends that all aliquots be "screened" via inductively coupled argon plasma emission spectrometry (ICP) for B, Ca, Mg, Na, and K. For those elements (per sample) wherein concentrations are below instrumental detection limits, the aliquots will be reanalyzed using appropriate AAS techniques.

c) The Group No. 1 "plant-available" elements will be run on every sample via ICP or AAS, as particular elemental concentrations dictate. The Group No. 2 elements will be analyzed in the 0-4 and 4-12 inch depth increments only when site-specific conditions indicate that such information is necessary to the remedial action planning process. These metals can pose a threat to public health or welfare, or may inhibit crop production/cropland reclamation efforts.

d) Aluminum will be extracted with 1N KCl, followed by titration with 1N HCl; technical details are described in Grant W. Thomas, Exchangeable Cations, Method 9-4.2, pp. 163-164 In A. L. Page et al., 1982.

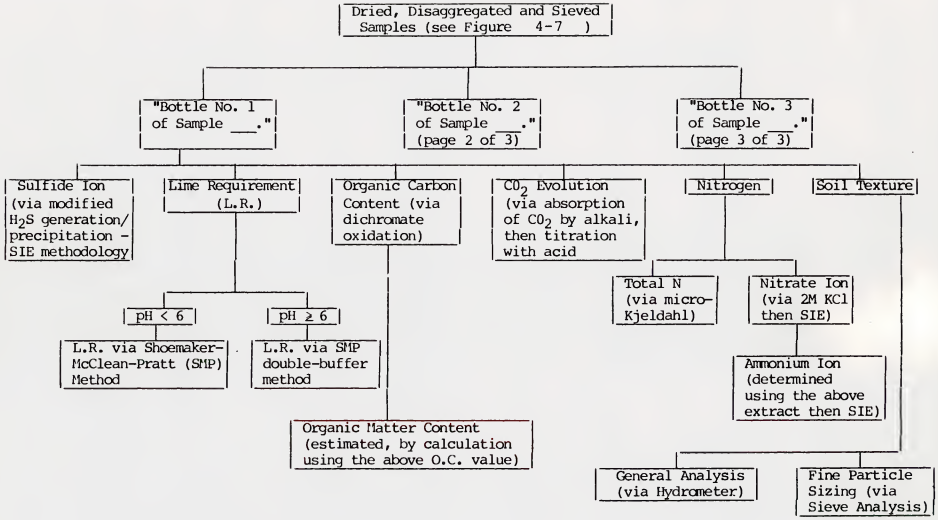

Dried, Disaggregated and Sieved Samples (see Figure 4-7)
"Bottle No. 1 of Sample ___."
"Bottle No. 2 of Sample ___." (page 2 of 3)
"Bottle No. 3 of Sample ___." (page 3 of 3)
Sulfide Ion (via modified H_2S generation/ precipitation - SIE methodology
Lime Requirement (L.R.)
Organic Carbon Content (via dichromate oxidation)
CO_2 Evolution (via absorption of CO_2 by alkali, then titration with acid
Nitrogen
Soil Texture
pH < 6
pH ≥ 6
L.R. via Shoemaker-McClean-Pratt (SMP) Method
L.R. via SMP double-buffer method
Organic Matter Content (estimated, by calculation using the above O.C. value)
Total N (via micro-Kjeldahl)
Nitrate Ion (via 2M KCl then SIE)
Ammonium Ion (determined using the above extract then SIE)
General Analysis (via Hydrometer)
Fine Particle Sizing (via Sieve Analysis)

FIGURE 4-8 —RECOMMENDED ANALYTICAL FLOW CHART FOR PROCESSING OF SOIL SAMPLES
(Page 1 of 3)

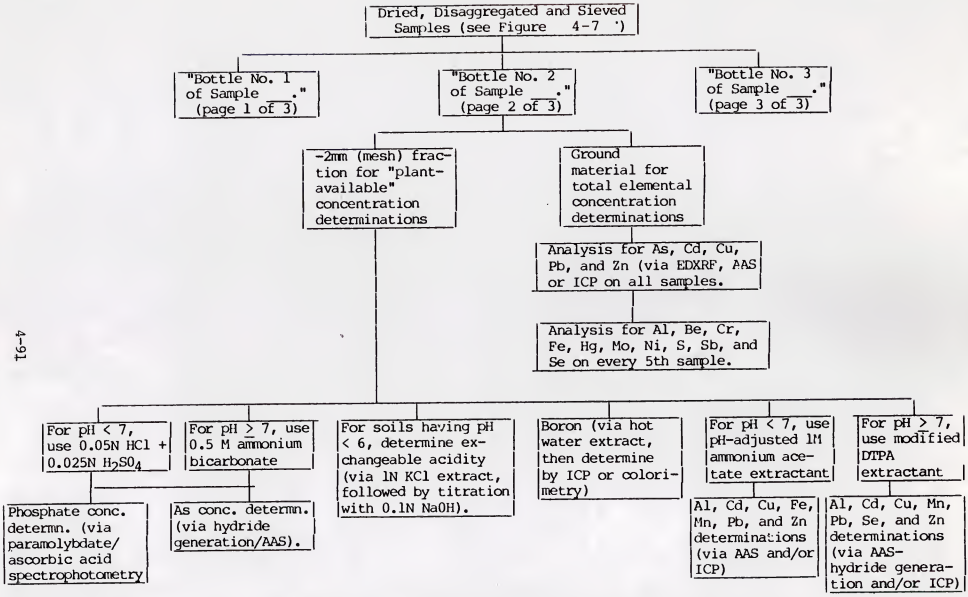

Dried, Disaggregated and Sieved Samples (see Figure 4-7 ')
"Bottle No. 1 of Sample ___." (page 1 of 3)
"Bottle No. 2 of Sample ___." (page 2 of 3)
"Bottle No. 3 of Sample ___." (page 3 of 3)
-2mm (mesh) fraction for "plant-available" concentration determinations
Ground material for total elemental concentration determinations
Analysis for As, Cd, Cu, Pb, and Zn (via EDXRF, AAS or ICP on all samples.
Analysis for Al, Be, Cr, Fe, Hg, Mo, Ni, S, Sb, and Se on every 5th sample.
For pH < 7, use 0.05N HCl + 0.025N H_2SO_4
For pH ≥ 7, use 0.5 M ammonium bicarbonate
For soils having pH < 6, determine exchangeable acidity (via 1N KCl extract, followed by titration with 0.1N NaOH).
Boron (via hot water extract, then determine by ICP or colorimetry)
For pH < 7, use pH-adjusted 1M ammonium acetate extractant
For pH ≥ 7, use modified DTPA extractant
Phosphate conc. determn. (via paramolybdate/ascorbic acid spectrophotometry
As conc. determn. (via hydride generation/AAS).
Al, Cd, Cu, Fe, Mn, Pb, and Zn determinations (via AAS and/or ICP)
Al, Cd, Cu, Mn, Pb, Se, and Zn determinations (via AAS-hydride generation and/or ICP)

FIGURE 4-8 —RECOMMENDED ANALYTICAL FLOW CHART FOR PROCESSING OF SOIL SAMPLES
(Page 2 of 3)

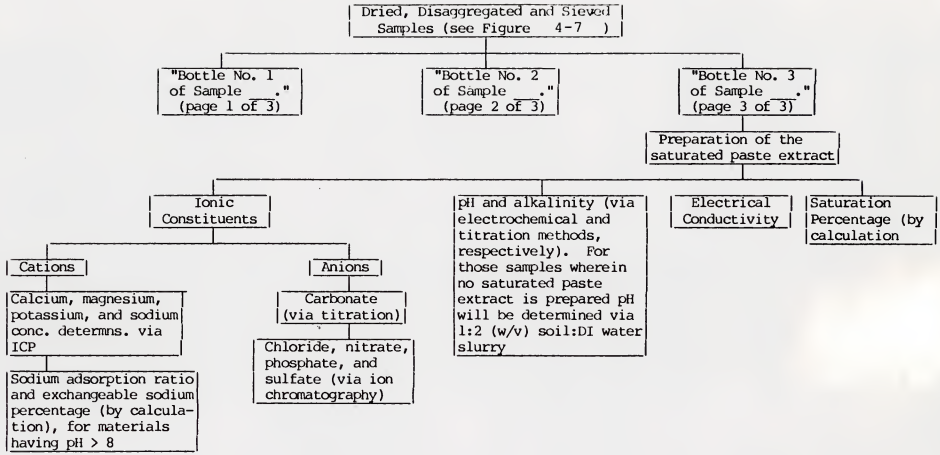

Dried, Disaggregated and Sieved Samples (see Figure 4-7)
"Bottle No. 1 of Sample ___." (page 1 of 3)
"Bottle No. 2 of Sample ___." (page 2 of 3)
"Bottle No. 3 of Sample ___." (page 3 of 3)
Preparation of the saturated paste extract
Ionic Constituents
pH and alkalinity (via electrochemical and titration methods, respectively). For those samples wherein no saturated paste extract is prepared pH will be determined via 1:2 (w/v) soil:DI water slurry
Electrical Conductivity
Saturation Percentage (by calculation
Cations
Anions
Calcium, magnesium, potassium, and sodium conc. determns. via ICP
Sodium adsorption ratio and exchangeable sodium percentage (by calculation), for materials having pH > 8
Carbonate (via titration)
Chloride, nitrate, phosphate, and sulfate (via ion chromatography)

FIGURE 4-8 —RECOMMENDED ANALYTICAL FLOW CHART FOR PROCESSING OF SOIL SAMPLES
(Page 3 of 3)

4.4.13.5 Plant-Available Trace Element Data Reduction and Reporting

Soil extract analytical results are to be expressed as micrograms of metal or metalloid per gram of soil (air-dry weight). Such results will be calculated using the following equation:

$$\mu g \text{ metal or metalloid per gm (air-dried weight)} = ABC/D$$

where: A = µg/ml of metal/metalloid in sample extract

B = Final volume of sample extract

C = Dilution factor (e.g., 10 or 100), if necessary

D = Sample weight in grams (air-dried weight)

Samples whose extract concentrations are at or below the lowest working standard but which exceed the limit of detection (i.e., approximately three times the standard deviation of the "blank" concentration), will be reported. However, the values will be bracketed [ ], indicating that the results were detected but are below the lowest working standard. Samples at or below the detection limit are reported as N.D., (i.e., Not Detectable).

All required quality control (QC) data for each set of 20 samples will be listed on a separate form (e.g., Figure 4-9). The results will be reported for sets of 20 samples to the designated organizations on Sample Analysis Report Forms (e.g., Figure 4-10).

SILVER BOW CREEK/UPPER CLARK FORK RIVER STUDY

Report To:_____ Date Reported:_____

Distribution:_____ QC Report #:_____

_____ Sample #'s: (Sequence as Analyzed)

_____ _____

_____

Laboratory Name:_____

Laboratory Supervisor:_____ Analyst(s) Initials:_____

1. Reagent Blank: µg/ml_____

2. Field Blank: µg/ml_____

   Sample #_____

3. Sieve-Wash Blank: µg/ml (in wash water)_____

   Previous Soil Sample #_____

4. Calibration Control Sample: g/ml: µ
   Found:_____
   True:_____
   Source:_____ % Recovery:_____

5. Spike Extract Analysis: g/ml µ Sample Extract Result:_____

   Sample #_____ Spike Extract Result:_____

   Spike Added:_____

   % Recovery:_____

FIGURE 4-9.--SOIL SAMPLE QUALITY ASSURANCE FORM

SILVER BOW CREEK/UPPER CLARK FORK RIVER STUDY

Report To:_____ Date Reported:_____

Distribution:_____

_____

_____

Laboratory Name:_____

Date Sample Received	Field Sample ID	Lab Sample ID	Date Analysis(es) Performed, Analyst Initials	Date Analysis Completed, Analyst Initials	Results for Parameter_____, (Units) for Matrix _____

_____

Laboratory Supervisor

FIGURE 4-10 --SAMPLE ANALYSIS REPORT FORM

4.4.14 Crop Sample Acquisition Protocols

At a particular sampling period (and site location), approximately 500 grams (fresh weight) of aerial tissues will be harvested at each subplot. The biomass will be harvested via use of stainless steel clippers (or equivalent) at ~3 inches above ground-level. The aerial portions of the whole-plant acquired at the first subplot will be washed in a 0.01 percent solution of (phosphorus- and metal-free) Alconox, rinsed twice with clean tap water, then finally rinsed with D.I. water. The washed material will be shaken to remove excess (rinse) water and then placed in a clean, one-gallon capacity stainless steel container. The above process is repeated at each of the other three subplots (per site-crop species). Once the container is filled with washed-rinsed material from all four subplots, the biomass is blended together using a clean, stainless steel trowel. Approximately 200- to 400-grams of material is withdrawn randomly, and then placed in a second stainless steel bowl. The stems and leaves are separated from the fruiting bodies (e.g., seed heads) using stainless steel scissors (or equivalent). Each tissue type is placed into a separate clean paper bag (~24 oz. capacity), labeled appropriately, and then weighed to the nearest gram. At least 100 grams (fresh weight) of each tissue type should be acquired for each species sampled. The sealed bags are then placed in a cooler (~40°F) and remain there until received by sample bank personnel at the end of each field sampling day. In regards to potato fields, no aerial tissues will be sampled, unless they are consumed by livestock living in the vicinity. However,

approximately 400 grams of tubers will be acquired from within each 0.1-acre plot. The rinsed tubers will then be placed in paper bags and treated as discussed previously.

Upon completion of the crop materials sampling, surface (0-4 in.) and subsurface (4-12 and 12-28 in.) soils samples will be gathered at each subplot. The details for acquiring the composite, depth-integrated soil samples are presented in Appendix Section 4.4.12.

4.4.15 Laboratory Methods for Crop and Native Plant Analyses

Sample Preparation

Upon receipt at the sample bank, the field number per sample is recorded in the master sample log (record book). The chain-of-custody protocols discussed in Section 5.0 of the Quality Assurance Plan will be followed. The samples will be refrigerated at 3° to 5°C until they are prepared for analysis.

For each sample, approximately three-fourths of the total weight is transferred incrementally to an acid-washed glass dish. The other one-fourth of the sample remains in the original collection sack; it is stored frozen until written permission is received from the MDHES to dispose of it. The vegetative biomass in the dish is chopped into $\leq$ 10 cm. lengths (or cubic cm. cubes for potato samples) with a clean stainless steel razor blade or scalpel. The seedhead/fruiting body, previously separated from the vegetative portion (e.g., leaves, stem) of the sample while in the field, will probably not require this chopping procedure. Between samples, the dish and blade are first washed in a dilute soap (e.g., 0.01% Alconox) solution, then successively rinsed with 30 percent hydrogen peroxide and D.I. water, and then air-dried.

Each chopped tissue subsample is then placed into a clean, dry 250- to 800-ml. beaker, the size used being determined by the particular sample volume. The labeled beakers are dried in a forced-draft oven

at 40 ± 2°C for up to 48 hours, (or until clearly dry in appearance). If possible, the plant drying facilities should be different than those used for preparing other sample types (e.g., soils, river sediments). The plant drying areas will be vacuumed thoroughly between sample batches. At these times, the inner surfaces will be wiped down with a clean cloth or sponge that has been moistened with D.I. water.

When the samples appear to be dry, they are removed from the oven and ground successively to pass a 20-mesh, then 40-mesh, stainless steel screen via use of an intermediate model Wiley® mill. The first few grams of each freshly ground sample should be disposed of, as such material could be contaminated by traces of the previously ground sample. The remainder is then collected in a vial of appropriate size for later chemical analysis. The mill must be either vacuum-cleaned or blown out with compressed air after the grinding of each sample. The ground sample is collected in a clean 100 to 200 ml. volume glass or plastic vial. The labeled, capped vials are stored in the sample bank (under cool, dry conditions). If a considerable analytical backlog occurs, the prepared samples will be stored at 0 ± 1°C. When ready for processing, they would then be thawed, dried to constant weight and a subsample then removed for digestion.

Sample Digestion Prior to Trace Metals Analysis

The dried, ground sample is hand-mixed in its storage vial by gentle tumbling for approximately 10 to 15 seconds. Approximately one gram of sample is weighed into a tared 150 to 250 ml. graduated pyrex beaker; the beaker plus sample is dried at 40 ± 5°C for approximately one hour, cooled to room temperature and then weighed to the nearest 0.1 mg via use of an analytical balance. If a replicate is required to meet internal QC protocols, a second one gram portion is then withdrawn from the storage vial and processed in the same manner as described above.

The sample is then ready for perchloric acid digestion as described by Allen (1974), modified by an H_2O_2 addition.

Sample Analysis Protocols

The determination of As, Cd, Cu, Pb, and Zn in plant materials will utilize flame or flameless AAS or ICP spectroscopic procedures. The actual instrumental technique utilized per sample will be dependent upon the particular element analyzed for and its concentration (per standard analyte volume), as the sensitivity of the particular determination varies from one instrument type to another. The use of these instruments will cover the dynamic (concentration) range expected for each of the particular elements to be analyzed for.

A Labconco® brand micro-Kjeldahl distillation unit or equivalent is used to determine % Kjeldahl nitrogen in soil and plant materials. The manufacturer's suggested methodology will be used.

The methodology described by Dollhopf et al. (1984) will be used to determine total-P content in sampled native and cultivated plant species.

4.4.16 Livestock Sampling Protocols

4.4.16.1 Blood Samples

Blood samples will be obtained from the jugular vein of each animal, regardless of species (i.e., cattle, horse, or sheep); vena puncture will utilize a disposable (single-use), 15 gauge stainless steel needle. "Four 10 ml safety monovets will be filled with blood from each animal. If for any reason the four monovets are not filled, this will be entered on the sample collection tag [Figure 4-11]. The four 10 ml monovets will contain ammonium heparin [i.e., serving as the anticoagulant]."

"The four monovents from each animal will be placed in a large sterile whirl pac which contains the Sample Collection Tag. An additional and identical Sample Collection Tag will be affixed to the outside of the whirl-pac. The whirl-pacs will be cooled on ice in styrofoam coolers for transportation to the interim storage area for processing. Coolers will be sealed with tape in the field. This seal must be intact when received at interim storage area," (Dollhopf et al. 1984, p. 54).

4.4.16.2 Hair and Wool Samples

Hair samples of approximately 5 to 10 grams weight will be obtained as high as possible on the withers of each horse or cattle speciman. Sample acquisition will use an electric clipper or scissors whose

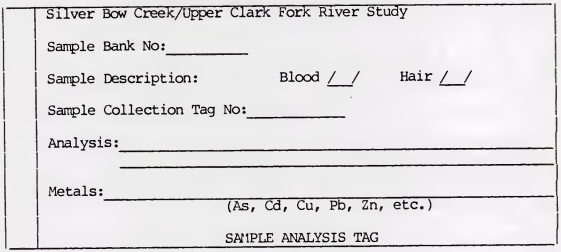

Silver Bow Creek/Upper Clark Fork River Study
Sample Bank No:
Sample Description: Blood / / Hair / /
Sample Collection Tag No:
Analysis:
Metals:
(As, Cd, Cu, Pb, Zn, etc.)
SAMPLE ANALYSIS TAG

FIGURE 4-11 —ALTERNATIVE SAMPLE ANALYSIS TAG FOR LIVESTOCK SAMPLES

Source: Dollhopf et al. 1984, p. 53.

cutting edge is made of stainless steel. Preferably, only pigmented hair samples will be acquired. In regards to sheep, approximately 10 grams are clipped (as above) in equal amounts from each animal's head, shoulder, and rear leg; equal weights of pigmented and non-pigmented wool should be collected from dual-colored animals. In order to minimize intra-sample contamination effects, the cutting edge will be made of stainless steel. The cutting unit will be decontaminated between samples as follows: wipe blade(s) with a Kimwipe moistened with dilute (0.01%) Alconox solution, rinse with D.I. water, and then dry with a (second) Kimwipe sheet. When sampling wool, the soapy wash must be preceeded by wiping the blade once or several times with a Kimwipe moistened with acetone or denatured ethanol. This step will aide in removing lanolin, etc., accumulation on the blade that was deposited there during the sampling process.

The hair and wool samples, "will be divided into three approximately equal amounts and placed in individual sterile whirl-pac bags. The three whirl-pac bags are placed in a larger whirl-pak which contains the Sample Collection Tag. An additional and identical Sample Collection Tag will be affixed to the outside of the large whirl-pac. Hair [and wool] samples will be transported with the blood samples to the interim storage area. Sample Collection Tags will be provided. Information for each animal in the field worklog and Sample Collection Tag will be consistent. Coolers will be sealed with tape in the field. This seal must be intact when received at the interim storage area," (Dollhopf et al. 1984, pp. 54-55).

4.4.16.3 Field Blanks and Duplicates

"Field Blanks will be monovets containing [D.I.] water and will be submitted at 5% of the sampled animals. These will be injected into the sample stream at a rate of 5 per 100 samples. Each field blank will consist of (4) 10 ml monovets filled with [D.I.] water. Field blanks for hair [and wool] samples will be [D.I.] water and will be submitted at the rate of 5 per 100 samples. This will be prepared in the field and will remain in the field sample storage container.

"The blood from each animal is collected in quadruplicate. Two 10 ml monovets are to be used for determination of metal concentrations; the third monovet is to be used as a duplicate at the rate of 5% (5 per 100); the fourth 10 ml monovet will be held in the Sample Bank.

"Hair [and wool] samples which have been divided into three whirl-pac bags are considered triplicate samples. One subsample will be used for metal determinations; the second is to be used as a duplicate at the rate of 5% (5 per 100); the third subsample will be held in the Sample Bank," (Dollhopf et al, 1984, pp. 55-56).

4.4.16.4 Sample Labeling

The sample collection tags will be numbered serially, preferably starting with a project identifier code (e.g., SBC represents the

Silver Bow Creek Project). The suggested format is shown in Figure 4-11. "The tags will be preprinted to ensure that all required information is provided on each tag. Each collected sample including field blanks, shall have a completely filled in sample collection tag in the whirl-pac bag and an identical sample collection tag attached to it. Each blood sample will consist of four 10 ml monovets collected from each animal in the sample whirl-pac bag. Each hair [or wool] sample will consist of three subsamples in individual whirl-pac bags which are enclosed in a larger whirl-pac bag. Field blanks shall be identified in the remarks section of the tag and by specific sampling site identification code number.

"The veterinarian who physically collects the sample is the SAMPLER and signs the sample collection tag. The SAMPLER also initiates the chain-of-custody record for transfer of samples to the sample bank, located in the interim storage area," (Dollhopf et al. 1984, pp. 52-53).

"After the samples have been transported to the Sample Bank area and documented in the Master Log, they [could] be renumbered and identified with a new sample analysis tag. This renumbering step [would allow] the submittal of duplicate samples, field blanks, and QC samples as blinds to the analytical facility. The recommended sample analysis tag is shown in [Figure 4-11]," (Dollhopf et al. 1984, p. 53).

4.4.16.5 Sample Bank and Chain-of-Custody

"In the field, the veterinarian will have responsibility for the assigned biological samples; that is, the SAMPLER, who signs the field work log and Sample Collection Tags will ensure that the samples reach the sample bank or the interim storage area. He also initiates the chain of custody form [Figure 5-1 in the Quality Assurance Plan]. Once the samples are in the interim storage area, samples will be transferred to a clerk who will log the samples in a master log book. [A sample renumbering step would enable] the submittal of duplicate samples, field blanks, and QC samples as blinds to the analytical laboratory. The original sample collection tag number is recorded in the Master Log and the tag itself filed in the interim storage area. Samples will be in locked storage, locked refrigeration for blood samples, until transferred to the analytical facility. Traceability of samples from animal to laboratory analysis is required. Therefore, cross indexing of all Sample Collection Tag numbers and Sample Analytical Tag numbers must be made in the Master Log Book," (Dollhopf et al. 1984, p. 56).

4.4.16.6 Sample Preparation for Transfer and/or Storage

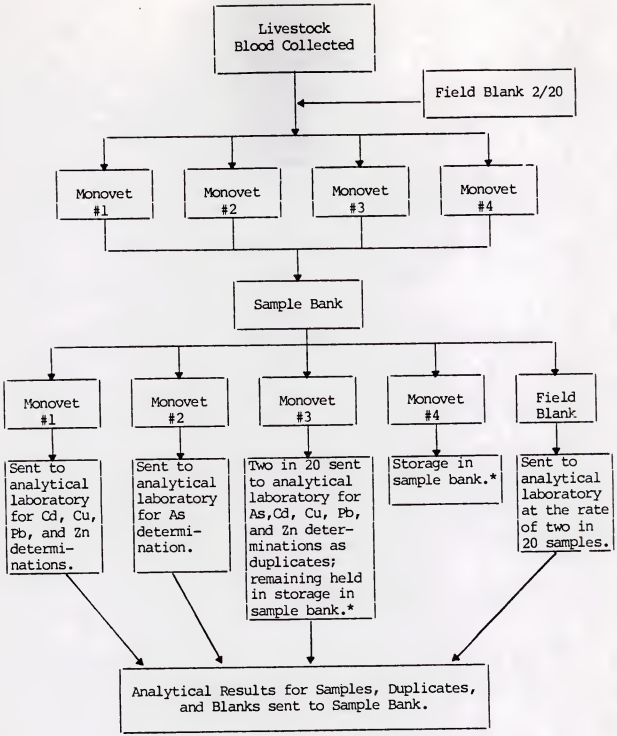
Sample Splits and Transfer

"The first two monovets from each set of four, containing heparinized blood, with Sample Analysis Tag attached will be readied for shipment to the analytical facility. One monovet will be used for [Cu, Cd,

Pb, and Zn] determinations, the second for As determination. These will be placed in whirl-pac bags. One in every 20 samples will be a duplicate pulled from the third set of monovets. These will be readied for shipment to the analytical facility with Sample Analysis Tag attached to the whirl-pac bag. One in every 20 samples will be a field blank. These will be readied in the same manner. All samples, duplicates, and field blank will be transported on ice to the analytical facility. The remaining monovets, the third set from which duplicates have been removed and the fourth set, will be stored in the Sample Bank. [The flow chart depicting the above process is shown in Figure 4-12.]

"Hair samples which have been split into three subsamples and assigned a Sample Analysis Tag will be readied for shipment to the analytical facility. One in every 20 hair [or wool] samples will be a field blank. One in every 20 hair [or wool] samples will be a duplicate hair [or wool] sample. These will be transported with one full set of subsamples. The duplicate will be taken from the second set of subsamples," (Dollhopf et al. 1984, p. 57).

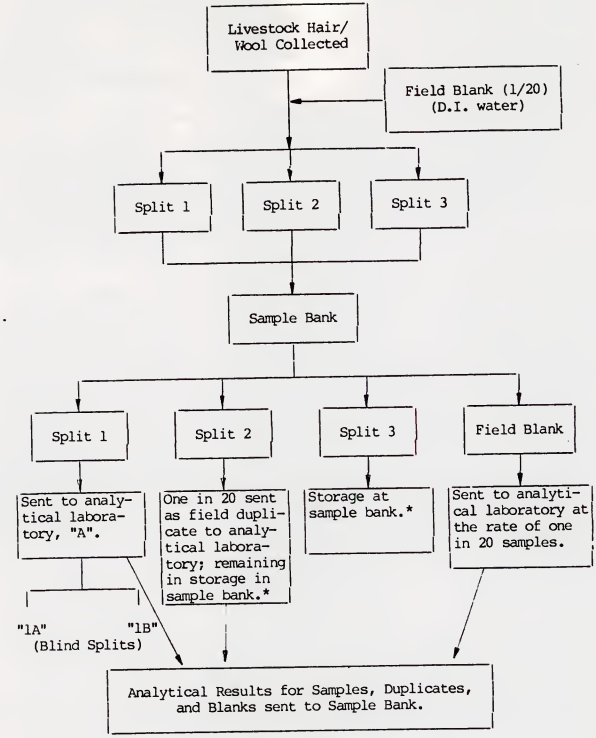
"The third set of subsamples and the remaining samples from the second set will be stored in the sample bank. Chain of custody forms [Figure 5-1 in the Quality Assurance Plan] will accompany samples to the analytical facility with a copy retained in the interim storage area. [The flow chart depicting the above process is shown in Figure 4-13.]


Livestock Blood Collected
Field Blank 2/20
Monovet #1
Monovet #2
Monovet #3
Monovet #4
Sample Bank
Monovet #1
Monovet #2
Monovet #3
Monovet #4
Field Blank
Sent to analytical laboratory for Cd, Cu, Pb, and Zn determi-nations.
Sent to analytical laboratory for As determi-nation.
Two in 20 sent to analytical laboratory for As,Cd, Cu, Pb, and Zn deter-minations as duplicates; remaining held in storage in sample bank.*
Storage in sample bank.*
Sent to analytical laboratory at the rate of two in 20 samples.
Analytical Results for Samples, Duplicates, and Blanks sent to Sample Bank.

* These samples may be sent to another analytical facility to confirm initial determination.

FIGURE 4-12 --FLOW CHART SHOWING LIVESTOCK BLOOD SAMPLE HANDLING SCHEME

Source: Dollhopf et al. 1984, p. 58b.


Livestock Hair/ Wool Collected
Field Blank (1/20) (D.I. water)
Split 1
Split 2
Split 3
Sample Bank
Split 1
Split 2
Split 3
Field Blank
Sent to analytical laboratory, "A".
One in 20 sent as field duplicate to analytical laboratory; remaining in storage in sample bank.*
Storage at sample bank.*
Sent to analytical laboratory at the rate of one in 20 samples.
"1A"
"1B"
(Blind Splits)
Analytical Results for Samples, Duplicates, and Blanks sent to Sample Bank.

* These samples may be sent to another analytical facility ("B") to confirm initial determinations.

FIGURE 4- 13—FLOW CHART SHOWING LIVESTOCK HAIR AND WOOL SAMPLE HANDLING SCHEME

Source: Dollhopf et al. 1984, p. 58a.

4.4.16.7 Sample Storage

"Blood and hair samples which are not used for metal determinations will be frozen and archived in the sample bank. These may be used for reference laboratory analysis," (Dollhopf et al. 1984, p. 58).

4.4.17 Livestock Tissue Analytical Methods

4.4.17.1 Blood Samples

"Blood samples for [Cd, Cu, Pb, and Zn] determinations will be digested in acid and analyzed by electrothermal atomic absorption spectrometry. An appropriate sample volume will be placed in a 125 ml erlenmeyer flask with 25 ml of concentrated HNO_3 added (ULTREX or INSTRA-ANALYZED). The sample flask is heated slowly on a hot plate until a clear solution is obtained and then allowed to cool. The solution is transferred to a cleaned 50 ml volumetric flask and brought to volume with [D.I.] water.

"Blood samples for As determinations will be digested in a triacid mixture and analyzed by atomic absorption spectrometry after formation of the volatile hydride, arsine. An appropriate sample volume will be placed in 125 ml erlenmeyer flasks with 30 ml of 1:5 $HClO_4$: HNO_3. The flask is heated on a hot plate until sample volume is reduced by one-half and then 10 ml of 1:1 HNO_3:H_2SO_4 are added. Heat is continued until sample volume is approximately 5 ml. The solution is allowed to cool, transferred to a 50 ml volumetric flask which contains 25 ml of concentrated HCl. After cooling the volumetric flask is brought to volume with [D.I.] H_2O. All acids used are Ultrex or Instra-analyzed," (Dollhopf *et al.* 1984, pp. 65-66).

4.4.17.2 Hair and Wool Samples

Prior to wet ashing and subsequent chemical analysis, trace element contamination adsorbed onto the surface of the hair shafts or wool fibers must be removed. Thus, all samples will be washed initially in ~50 ml of a, "0.75% commercial detergent (Ammonium lauryl sulfate) solution for 15 minutes with stirring and mechanical agitation. Hair is washed free of detergent with tap H_2O, placed on filter paper, and rinsed four times with copious amounts of [D.I.] H_2O," (Dollhopf et al. 1984, p. 66). If the hair sample is particularly dirty, or is instead composed of wool, then more drastic cleansing methods will follow those discussed above. One possible approach, proposed by the International Atomic Energy Agency and World Health Organization (1975), is stated below:

> "The hair should be cleaned with Soxhlet extraction using diethyl ether for two hours. This removes the oxidized natural greases from the outside of the hair but has little effect on the major or minor elements in the hair itself," (quoted from Jenkins 1979, p. 39).

The treated hair and wool samples are finally dried for two to four hours at 60-70°C. A one gram subsample, weighed to the nearest 0.1 mg, is then withdrawn for trace element analysis.

The weighed samples will be digested in the same manner as discussed for blood. The analytical step will utilize flame or electrothermal (carbon furnace) AAS spectrophotometry when determining Cd, Cu, Pb, and Zn contents.

A separate subsample, also weighing)1 gm (to the nearest 0.1 mg), will be digested in the triacid mixture utilized for As determinations in whole blood. The arsenic per sample volume is then converted to the arsine (volatile hydride) form, and then analyzed by AAS spectrophotometry.

4.4.18 Analysis of Agricultural Data

4.4.18.1 Preparation of Descriptive Statistics

The data contained in the soil-cropland site description forms and livestock field sampling work log forms will be reduced to summary tables. The information to be contained in the respective tables (i.e., for each of the three agricultural components) is discussed below.

In regards to soils, the respective arithmetic mean and standard deviation will be presented for each quantifiable parameter. Qualitative types of categorized data will also be presented and discussed. An overview of the information to be reported is shown in Table 4-7. The associated text will state the number of cultivated and rangeland soil sites sampled and demarcate their locations on a suitably-scaled map (e.g., Exhibit 1).

The data summaries for croplands sampling will include the following. First, it will present the approximate acreage sampled per crop or rangeland type. Second, the number and location of sampling sites per crop or range type will be stated; this will probably occur by reference to the preceeding discussions on soils. Thirdly, statistical summaries ($\bar{x} \pm sd$) of leaf chlorosis and leaf necrosis cases observed per crop type will be tabulated and evaluated then against the pertinent laboratory data. These efforts, achieved by calculation of Kendall and Spearman rank correlation coefficients, may

TABLE 4-7 . ENVISIONED FORMAT AND CONTENTS FOR SOILS-RELATED DESCRIPTIVE STATISTICS

PART A. QUANTITATIVE CATEGORIES

Category	Parameter	Comments
Biological	• Rooting Depth (in.)	$\bar{x}$ ± sd values per crop type, and soil series, if known.
Chemical	• pH (field measurement)	Ditto.
	• Presence of saline or alkaline surface crusts.	Number of such sites, per parameter, expressed on the basis of crop/range type and soil series or general taxonomy, as can be determined.
Physical	• Aspect (°)	$\bar{x}$ ± sd values per crop type, and soil series, if known.
	• Coarse (rock) fragments	Number of such sites encountered per crop type and soil series, if known.
	• Elevation (ft)	$\bar{x}$ ± sd values per crop type, and soil series, if known.
	• Moisture (field measurement)	Ditto.
	• Permeability (in/hr)	Ditto.
	• Presence of ground water, and depth from surface (in. or ft)	Number of such sites encountered per crop type and soil series, if known; $\bar{x}$ ± sd values for depth statistics.
	• Slope (%)	$\bar{x}$ ± sd values per crop type and soil series, if known.

TABLE 4-7 . ENVISIONED FORMAT AND CONTENTS FOR SOILS-RELATED DESCRIPTIVE STATISTICS (CONTINUED)

PART B. QUALITATIVE CATEGORIES

Category	Parameter	Comments
Physical	• USDA Soil Texture (field measurement)	Nurber of sites per textural class within each crop type and soil series, if known.
	• USDI wind/water erosion severity classes (field observations)	Number of sites per evaluation class for each crop type and soil series, if known.
	• Unusual characteristics (field observations/evaluations)	Number of sites where unusual color or texture characteristics were observed.

identify phytotoxic responses (in a given crop) to a deficient or excessive concentration of a particular element. Finally, the tentative listing of those "hyperaccumulator" plant species observed (if any), along with respective habitat conditions, will be presented and discussed. These discussions will include any case histories gleaned from livestock owners regarding poisoning by locoweed, lupine, etc., and their locations of occurrence.

The livestock-related data summaries will demarcate sampling site locations, and present sample statistics ($\bar{x} \pm sd$) per species. Furthermore, species-specific summaries of animals exhibiting one (or several) clinical signs possibly indicating "heavy metal" toxicosis (e.g., "roaring" in Pb-intoxicated horses) will be tabulated. These data will be compared against trace element analytical data from tissues gathered from the affected animals. Comparison of the clinical and chemical data will allow a preliminary determination on whether or not trace element poisoning is a valid diagnosis.

Laboratory Data

The trace element data for soil, crop, and livestock materials will be tabulated by the respective arithmetic mean, standard deviation, and coefficient of variation (CV) for each of the element-matrix combinations (e.g., arsenic levels in surface soil). For each such combination, a histogram displaying the frequency of occurrence of each particular concentration interval will be prepared. As most of

the subsequently prepared frequency polygons probably will be non-Gaussian in shape (for non-standardized data), testing of the degree of deviation from "normality" via kurtosis and skew calculations will be done also. The general format for displaying trace element data for soils and crops is shown in Part A of Table 4-8. Part B of this figure presents an hypothetical histogram and subsequently prepared frequency polygon. Table 4-9 presents the proposed format for tabulating livestock trace element data. The graphical display of such information could use the same format as shown in Part B of Table 4-8.

In order to assess the essential credibility of the above analytical results, a summary of statistical analyses performed on the various Quality Control (QC) data (see Section 7.2 of the Quality Assurance Plan) will be prepared. Thus, for each matrix-trace element combination, the arithmetic mean, standard deviation, CV and number of samples analyzed for each of the QC parameters will be calculated and tabulated. The QC parameters will include: reagent blanks; field blanks; split extracts (as % of original extract); total trace element results for duplicate samples; spiked extract (as % recovery of spike); calibration check standards; calibration control (e.g., EPA water quality check standards); blind split samples; and NBS Standard Reference Materials (as appropriate). For both the case of sample data presentation and for QC data presentation, the numerical and graphical (statistical) results will be accompanied by text of sufficient clarity to assure appropriate interpretation of them.

TABLE 4-8 . TENTATIVE FORMATS FOR PRESENTATION OF DESCRIPTIVE STATISTICS FOR THE CROP-SOILS TRACE ELEMENT DATA

PART A. TABULAR FORMATS

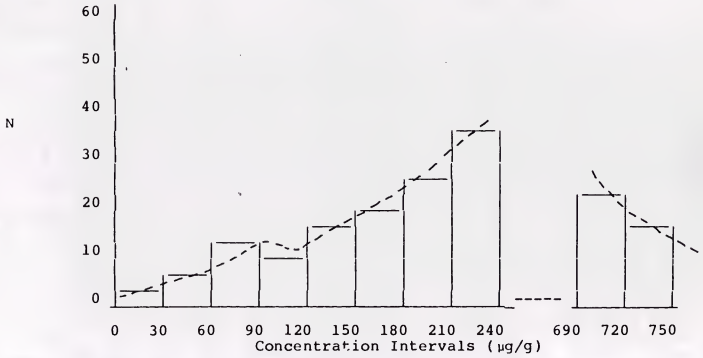
	Soil/Depth Interval (in.)		
Element Concentration (µg/g)	0-4	4-12	12-28
As	$\bar{x}$ ± sd; CV(N)[a]	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV (N)
Cd	"	"	"
Cu	"	"	"
Pb	"	"	"
Zn	"	"	"

Element Concentration (µg/g)	Alfalfa	Tame Pasture/ Hay	Barley	Oats
As	$\bar{x}$ ± sd; CV(N)[a]	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)
Cd	"	"	"	"
Cu	"	"	"	"
Pb	"	"	"	"
Zn	"	"	"	"

Element Concentration (µg/g)	Spring Wheat	Winter Wheat	Potatoes	Native Range[b]
As	$\bar{x}$ ± sd; CV(N)[a]	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)
Cd	"	"	"	"
Cu	"	"	"	"
Pb	"	"	"	"
Zn	"	"	"	"

TABLE 4-8 TENTATIVE FORMATS FOR PRESENTATION OF DESCRIPTIVE STATISTICS FOR THE CROP-SOILS TRACE ELEMENT DATA (CONTINUED)

PART B. HISTOGRAM AND FREQUENCY POLYGON FORMAT (HYPOTHETICAL EXAMPLE)[c]



Notes:

a) The $\bar{x}$ ± sd represents the arithmetic sample mean and standard deviation, respectively, for the particular element-matrix combination; CV represents the coefficient of variation of the sample mean; and (N) represents sample number used to calculate the particular statistics.

b) Includes various non-irrigated "native" rangeland plant species.

c) The dashed line represents the frequency polygon; boxes represent the histogram.

TABLE 4-9. TENTATIVE FORMAT FOR PRESENTATION OF DESCRIPTIVE STATISTICS FOR THE LIVESTOCK TRACE ELEMENT DATA

Livestock Species	Element	Blood	Hair/Wool
Cattle	As	$\bar{x}$ ± sd; CV(N)[a]	$\bar{x}$ ± sd; CV(N)[a]
	Cd	"	"
	Cu	"	"
	Pb	"	"
	Zn	"	"
Horses	As	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)
	Cd	"	"
	Cu	"	"
	Pb	"	"
	Zn	"	"
Sheep	As	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)
	Cd	"	"
	Cu	"	"
	Pb	"	"
	Zn	"	"

Note: a) The $\bar{x}$ ± sd represents the arithmetic sample mean and standard deviation, respectively, for the particular element-matrix combination; CV represents the coefficient of variation of the sample mean; and (N) represents the sample number used to calculate the particular statistics.

TABLE 4-8 TENTATIVE FORMATS FOR PRESENTATION OF DESCRIPTIVE STATISTICS FOR THE CROP-SOILS TRACE ELEMENT DATA (CONTINUED)

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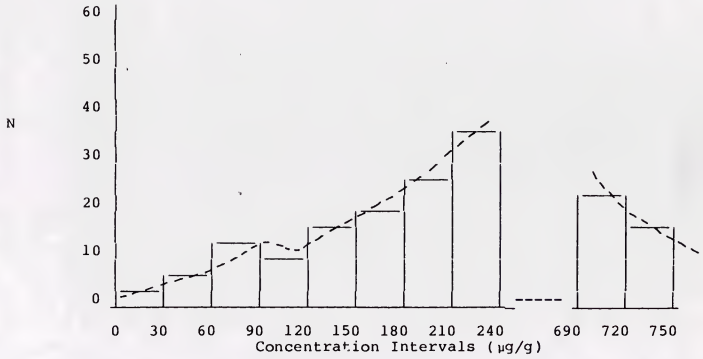

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4.4.18.2 Preparation of Analytical Statistics

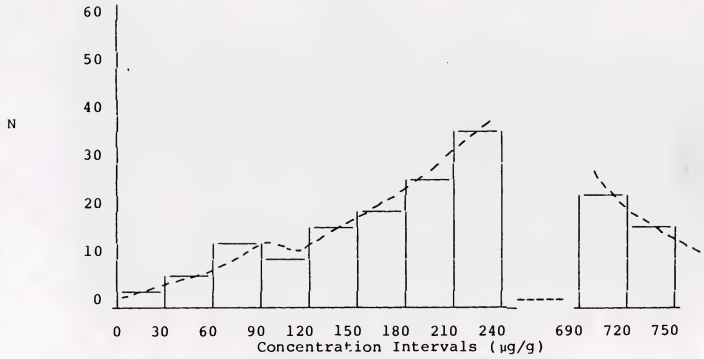
Soils

The initial step in generating soils-related analytical statistics is the preparation of trace element-specific concentration maps. On each map, the "plant-available" concentrations (e.g., of As) observed at each sampling site--and for all sampling depths--are plotted. Inspection of these maps will alow assessments of the following: 1) relative trace element mobilities (at a given site), and 2) whether site-specific mobilities are affected by differing soil conditions, agricultural management practices, etc. Each site can be evaluated then in terms of remedial action decision-making criteria. The definition of "toxic" levels of "heavy metals" remains a point of contention with respect to soils, plants, and livestock. "Toxicity" involves elemental solubility, ion exchange chemistry, pH-redox phenomenae, plant species' tolerance, soil-plant water potentials, and climatic factors. If, however, a certain set of toxic levels worthy of regionalized examination is required, then it will be best determined by the values as measured in the field.

Furthermore, it is recommended that one evaluate the contribution of (historical) stack-related emissions to the observed, site-specific, trace element burden in the soil. This could be accomplished by overlaying a particular map (generated by the present study) with the equivalent "far-field" concentration isopleth map,

TABLE 4-8 TENTATIVE FORMATS FOR PRESENTATION OF DESCRIPTIVE STATISTICS FOR THE CROP-SOILS TRACE ELEMENT DATA (CONTINUED)

PART B. HISTOGRAM AND FREQUENCY POLYGON FORMAT (HYPOTHETICAL EXAMPLE)[c]



Notes:

a) The $\bar{x}$ ± sd represents the arithmetic sample mean and standard deviation, respectively, for the particular element-matrix combination; CV represents the coefficient of variation of the sample mean; and (N) represents sample number used to calculate the particular statistics.

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	Cu	"	"
	Pb	"	"
	Zn	"	"
Sheep	As	$\bar{x}$ ± sd; CV(N)	$\bar{x}$ ± sd; CV(N)
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	Cu	"	"
	Pb	"	"
	Zn	"	"

Note: a) The $\bar{x}$ ± sd represents the arithmetic sample mean and standard deviation, respectively, for the particular element-matrix combination; CV represents the coefficient of variation of the sample mean; and (N) represents the sample number used to calculate the particular statistics.

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Furthermore, it is recommended that one evaluate the contribution of (historical) stack-related emissions to the observed, site-specific, trace element burden in the soil. This could be accomplished by overlaying a particular map (generated by the present study) with the equivalent "far-field" concentration isopleth map,

if available. A more rigorous statistical evaluation of this concern would utilize the linear or non-linear regression analysis of the appropriately transformed data (e.g., via Z-scores, $base_{10}$ logarithms).

For those fields designated as being in need of remedial action, the design of effective plans will be aided by multiple correlation analyses, and possibly stepwise multivariate regression analyses, between various soil data types. For a given sample depth (within a given field or problem area), multiple correlation analysis will test the significance of associations between pH data, "plant-available" trace element (concentration) data, and other measured parameters (e.g., organic carbon, various plant macronutrient concentrations). The resulting matrix will aid in comprehending how the various parameters are associated with each other. Secondly, these efforts will aid in evaluating the probable success of a particular remedial action plan proposed for a given field or problem type. The subsequent use of partial correlation and stepwise multivariate regression techniques will test further the potential relationships between sampling depth and selected soil parameters (for sites within a defined stream segment, sector, or problem type).

Crops

Soil enrichment factors and soil:plant concentration (uptake) ratios will be determined for the designated contaminated and control

areas. These ratios will be used to evaluate sites for remedial action. The soil enrichment factor, EF, for a particular element present at a particular sampling site is defined as follows:

$$EF_i = \frac{\text{mean concentration of } i^{th} \text{ element at the sampling site}}{\text{critical abundance (concentration) of } i^{th} \text{ element in the applicable geological parent material(s)}}$$

The soil:plant uptake ratio, SP, for a given trace element-crop species combination present within a given study sector or stream segment is calculated by the formula given below:

$$SP_i = \frac{\text{mean concentration of } i^{th} \text{ element in the given crop species}}{\text{mean concentration of } i^{th} \text{ element in the soil's rooting zone (4-12 in)}}$$

The EF and SP values (per element) will allow semiquantitative assessment of whether or not the observed elemental concentration exceeds the probable "geochemical background" concentration in a particular crop species. Such information could form an a posteriori rationale for demarcating certain geographic areas (or fields) as being in need of some form of remedial action.

In regards to more robust forms of analytical (data) testing, partial correlation and multivariate regression will be performed on a crop-by-crop (or species-by-species) basis to evaluate relationships between soils and crops. These tests will examine potential associations between: 1) distance/direction from the stack or 2) distance downstream from the headwaters of Silver Bow Creek (i.e., the

independent variables) and respective concentrations of As, Cd, Cu, Pb, Sc, and Zn (i.e., the dependent variables). For those crop species where significant relationships are observed (e.g., for α = 0.05) among one or both of the two conditions, a third "run" -- using the same software -- will occur. This third iteration will treat the Kjeldahl-nitrogen (or total phosphorus) concentrations (per crop species) as the dependent variable and the above trace elements as the independent variables.

Stepwise discriminant analyses of the laboratory data for each given crop species present in both the designated "clean-up" area(s) and "no-action" area(s) will be undertaken. The supposedly independent variables will include the five trace elements (i.e., excluding Sc) plus Kjeldahl-nitrogen (or some other macronutrient) concentrations. The variables used in computing the linear classification functions will be chosen in a stepwise manner.

Livestock

Initially, the various livestock-trace element data combinations will be tabulated in the format shown in Table 4-10. The tissue data sets will be coded so that any clinical sign(s) indicating potential heavy metal toxicosis (per animal sampled) can be identified. Calculation of the Spearman rank correlation coefficient will test independence or positive association of trace element contents between the two tissue types. In addition, those cases wherein one or both of the analytical values either equal or exceed

TABLE 4-10. EXAMPLE SHOWING SPEARMAN RANK CORRELATION EVALUATION, USING CATTLE-ARSENIC DATA

Sample No. (Clinical Codes)[a]	Hair Conc. (µg/g)	Rank[b,c]	Blood Conc. (µg/ml)	Rank[b,c]
C_1 (2,4,5)	5.1	28	0.055	20
C_2 (1,2)	2.0	31	0.050	34
C_3 (0)	0.6	47	0.048	43
:	:	:	:	:
C_{50} (1,4)	0.8	43	0.041	48

Notes: a) C_i represents animals numbered 1 through 50; clinical codes will be clearly defined, using various veterinary toxicology reference texts.

b) Concentration values are ranked from one (1) = highest to fifty (50) = lowest.

c) Spearman rank correlation coefficient determined by use of the following formula:

$$r_S = 1 - \left(\frac{6\sum(X_i - Y_i)^2}{n(n^2-1)} \right)$$

where n = number of pairs of observations; X_i = rank of x_i (i.e., concentration of trace element "a" in hair); Y_i = rank of y_i (i.e., concentration of trace element "a" in blood).

Tests are as follows: H_o: X and Y are independent variables ($\alpha = 0.05$)

H_i = X and Y are positively correlated ($\alpha = 0.05$)

the literature value indicating heavy metal toxicosis will be identified. Thirdly, the clinical sign(s) commonly associated with a particular type of trace element poisoning can be compared against specific symptoms and analytical data (for a given animal) to tentatively diagnose the presence of metal poisoning.

The above screening processes will identify and locate those cases of probable trace element toxicoses(per livestock species sampled). In such instances, multiple correlation analyses of trace element contents in materials ingested versus tissue levels is recommended. The objective of these tests is the evaluation of associations between trace element levels taken in through the soil, feed, and water sources with the apparently excessive level(s) observed in tissues taken from a particular, affected, animal. Ideally, these efforts will allow determination of relative contributions (of a given element) to the affected animal's diet. Once these properties are known, the appropriate remedial action(s) can be identified.

4.4.18.3 Data Synthesis and Interpretation

In summary, three major goals will be achieved by completion of this study. These accomplishments are as follows:

- Identification, location, and description of those cases or conditions wherein adverse biological consequences have apparently resulted from use of "heavy metal" contaminated irrigation water(s);

- Assessment of the biological significance of trace element accumulation throughout the particularly affected soil-crop-livestock food chain; and

- Evaluation and subsequent recommendation of further human health-related studies to refine the endangerment assessment results. In addition, preliminary recommendations for alleviating the observed site-specific (or problem-specific) concerns will be presented.

The soil-crop, livestock and human health-related investigation flow sheets, presented in subsection 2.2.3.1, will guide the overall task efforts. Evaluation of the various types of descriptive statistics in light of pertinent assessment criteria (Section 4.5) will satisfy the first objective, (above). The second objective will be met largely by implementing the "analytical" statistics program discussed previously, but guided also by the the various biological (toxicity) assessment criteria and supplemented by further literature review. The third objective will evaluate the (collective) results of the first two objectives, using those generic remedial actions discussed in Section 3.2.3 as starting points. Thus, site-specific or problem-specific (e.g., alkaline soils with high metals content) "clean-up" actions can be presented and evaluated. Those approaches judged to be practical (and cost-effective) will then be integrated ultimately into the overall remedial action design/planning efforts.

4.4.19 Bioassay Procedure

Testing Equipment: The test will be conducted using a flow-through toxicant dilution and delivery system. The proportional dilution apparatus should deliver five concentrations of contaminated water to duplicate exposure tanks and also deliver water used for dilution to duplicate control tanks. During testing organisms will be shielded from disturbances with curtains or partitions. A time device will be provided to control photo-period. A 15- to 30-minute transition period between light and dark periods has been suggested. However, special lighting precautions must be taken during incubation of embryos. This will be discussed in the test methodologies section.

Any testing equipment that will come into contact with testing solutions will not contain substances that can be leached or dissolved by aqueous solutions in amounts that can adversely affect fish. Testing equipment will also be chosen to minimize sorption of test materials from glass. Suggested materials to minimize leaching, dissolution, and sorption are glass, type 316 stainless steel, nylon, and fluoroplastics. Items made of neoprene rubber and other materials not previously mentioned will not be used unless a sensitive aquatic species can survive for 48 or 96 hours in static water in which the items are soaking.

An appropriate metering system will be used to accomodate the type and concentrations of the test material and the necessary flow

rates of the test solutions. Commonly used diluter systems incorporate such metering systems as pumps, "dipping birds," siphons, and solenoids. The system selected, however, will consistently supply the necessary concentrations of test material.

Test chambers will be constructed by welding stainless steel or by gluing double strength or stronger window glass with clear silicone adhesive. If extra beads of adhesive are needed for strength, they will be added on the outside. This procedure would prevent sorption of organochlorine and organophosphorus.

Embryos and young fish will be exposed in plastic incubation cups constructed by gluing stainless steel or nylon screen bottoms to lengths of glass tubing or bottles with bottoms cut off. Incubation cups may also be constructed by gluing nylon or stainless steel screen sides to Petri dishes. These chambers will be of sufficient size that embryos are not stacked upon each other. The cups will be suspended or arranged in a test chamber to ensure that the test solution flows regularly into and out of each cup and that the organisms remained submerged. The metering system, test chambers, and incubation cups will be constructed to minimize stress to organisms by crowding or by turbulence.

Calibration: The metering system will be calibrated before each test, and if necessary, during the test. This may include determining the flow rate through each chamber and measuring the concentration

of test material in each test chamber. The general operation of the metering system will be checked daily in the morning and afternoon throughout the test.

Flow Rates: The flow rate through each test chamber will be at least five volumes additions per 24 hours. At any particular time during the test, flow rates through the test chambers will not differ by more than 10% from any one test chamber to any other. However, the flow rates through all the test chambers may be changed simultaneously during the test as long as the concentration of the test material and test temperature remain acceptable.

Water may flow directly over the embryos in the incubation cups to ensure adequate water exchange. However, turbulence must be kept at a minimum.

Cleaning Equipment: At the end of every test, all equipment which will be used again will be immediately emptied, rinsed with water, cleaned by a procedure appropriate for removing the test material (acid to remove metals), and rinsed twice with deionized water. Metering systems and test chambers will be rinsed with dilution water just before use.

Dilution Water: The dilution water should not adversely affect the test organisms. For early life-stage tests, the minimal criteria

for acceptable dilution water is that healthy test organisms will survive and grow satisfactorily in it. It is also desirable that at least one species, preferably the test species, be able to reproduce satisfactorily in the dilution water.

The concentration of both total organic carbon and particulate matter should be less than 5 µg/litre. Filtration may be used to keep the concentrations of particulate matter acceptably low. The range of hardness of weekly dilution water samples should be less than 5 mg/litre or 10% of the average, whichever is higher. The location of the dilution water intake should minimize fluctuation in quality and maximize the concentration of dissolved oxygen. The concentration of dissolved oxygen in dilution water should be between 90% to 100% saturation to help ensure that dissolved oxygen concentrations are acceptable in test chambers.

Before starting the test the dilution water will be measured for: alkalinity, hardness, pH, particulate matter, total organic carbon, total organophosphorus pesticides, organic chlorine (or total organochlorine pesticides plus PCBs), chlorinated phenoxy herbicides, ammonia, cyanide, sulfide, bromide, chloride, fluoride, iodide, nitrate, phosphate, sulfate, calcium, magnesium, sodium, potassium, aluminum, arsenic, beryllium, boron, cadmium, chromium, cobalt, iron, lead, manganese, mercury, molybdenum, nickle, selenium, silver, and zinc. For this study it is recommended that water from the Fish Hatchery in Anaconda be used for dilution water.

Test Concentrations: Test concentrations will be based on the results of a flow-through acute toxicity test at least 96-hours long using the larval stage of the test species and the dilution water. The highest concentration in the early life-stage test will be no greater than the lowest concentration producing adverse effects in the acute test. The concentrations of test material in each treatment, except for the highest concentration and control, will be at least 50% of the next highest one. Test material shall be obtained from the Warm Springs Pond #2 discharge.

Fertilization of Gametes: Eggs from all females used will be completely mixed prior to allocating them to beakers used to represent each exposure chamber. Eggs in each beaker will be mixed in just enough toxicant solution (10°C) to barely cover the lot. The toxicant solution will be from the respective exposure chamber which each beaker represents. Semen will be added immediately after the eggs are placed in the toxicant solution. Eggs and semen will be gently and thoroughly mixed to ensure maximum fertilization. Eggs, semen, and water will sit for two to five minutes after mixing and then the semen, broken eggs, and any blood clots will be rinsed from the eggs. The rinse solution will be the appropriate toxicant concentration for that fertilization beaker.

Test Procedure For Embryos: The early life history tests will consist of duplicate control treatments and a geometric series of five duplicate concentrations of the test material as previously described in the Test Concentrations Section. Thirty embryos per

replicate treatment will be placed in each chamber. The treatment water will be at 10°C and lighting conditions used will be dim incandescent lights (<20 ft-candles) or total darkness. Daily inspections of embryos can be made with a flashlight or brighter incandescent or fluorescent source.

Test Duration: The duration of the flow-through test will be at least 30 days post swim-up. All survivors growth should be determined by weighing to the nearest 0.01 gram and by measuring standard length to the nearest millimeter.

Data Collection: Infertile eggs, dead embryos, and dead alevins will be carefully removed with a pipet whose bore slightly exceeds the egg diameter. Unfertilized eggs and dead embryos can be discerned by a white coloration in comparison to a yellow coloration of living embryos. Dead embryos in the pre-eyed stage will be removed with extreme care. Stage of development will be determined by using Stockard's Solution (85:6:5:4-water, glycerin, formalin and glacial acetic acid, respectively) and properly recorded. Age of the dead embryos, extent of embryo mortality, and severity of any fungal infection will be recorded. When hatching starts, the number of embryos hatched and the number of physically abnormal fish and mortalities will be recorded daily. In addition any abnormal behavior should also be recorded. Criteria for death of young fish include: immobility-especially lack of respiratory movement, white opaque coloration, and lack of reaction to gentle prodding. Deaths of young fish will be recorded daily and dead

fish removed. At the end of the test, fish growth will be determined by weighing to the nearest 0.01 gram and by measuring standard length to the nearest millimeter.

Feeding: At 10°C hatching occurs by about 41 days for brown trout. At swim-up, alevins will be released to the larger exposure chamber. Post swim-up alevins will be fed at least 4 times daily with a starter grade commercial trout starter. They will be fed at a relatively high rate of food consumption (>4% diet dry weight/fish wet weight/day).

Data Collection On Test Solutions: For freshwater dilution water, hardness, alkalinity, pH, dissolved oxygen, and conductivity will be measured at the beginning and end of the test and at least once every two weeks during the test. Throughout the test the maximum and minimum temperature in at least one chamber will be recorded daily. Test material concentration in each test solution will be measured frequently enough to establish the average concentration and its variability. During normal flows As, Cd, Hg, Cu, Zn, and Fe should be measured at least once every two weeks. If runoff increases by a significant amount during testing then measurements will be made at least weekly.

Data Analysis: Maximum information will have been gained from the chronic flow through toxicity test if at least one of the following criteria is significantly different ($\alpha = 0.05$) when control results are compared with treatment results:

- Percent fertilization;
- Percent mortality; and
- Percent growth.

These measures are all concentration-dependent; therefore, an important measure of effect would be changes in biomass per treatment.

Preliminary and diagnostic graphical displays will be the first data analysis method. These graphical displays will compare the following:

- Effect of the treatment concentration on the fertilization (%) of gametes;
- Effect of the treatment concentration on the mortality (%) of embryos exposed up to time of hatching;
- Effect of the treatment concentration on the mortality (%) of brown trout exposed up to termination of the test;
- Effect of the treatment concentration on the mean total length of brown trout exposed up to termination of the test; and
- Effect of the treatment concentration on the mean total weight of brown trout exposed up to termination of the test.

There is potential for differences in frequency distributions between treated and control populations. Non-parametric statistics will be used because of this potential for experimental variability. Significant differences in fertilization, hatching success, embryo mortality, fish mortality, fish weight, and fish length can be determined within and among the controls and experimental groups by such tests as the Kruskal-Wallis test. Differences found to be significant can then be ranked using such tests as Dunn's Multiple Comparison Test.

The maximum acceptable toxic concentration (MATC) for brown trout will be determined using the most sensitive phase of the test. The MATC using that particular phase is less than or equal to the highest concentration where no test organisms were affected.

Accuracy and Precision In Toxicity Testing: Inherent to any test are numerous details which are specific to each situation and variation in equipment. The toxicology work plan has incorporated all essential materials to ensure a valid test. However, it is highly recommended that standard practices for conducting toxicity tests be reviewed before and during actual testing.

Several important considerations and facts to ensure a safe and valid test are included in the following:

- Human contact with all test materials and solutions of them

should be minimized by using dip nets and by wearing appropriate clothing;

- If clogging of screens in incubation cups is such that they require changing, all cups should be changed to minimize differences in growth not related to the test materials;

- For each treatment the highest measured concentration divided by the lowest measured concentration should be less than two;

- Embryos are especially sensitive during the pre-eyed stage to any type of disturbance;

- If more than about a third of the control embryos die, or if concentration-related effects occur in the first 48 hours it probably will be cost-effective to restart the test;

- For a chronic flow-through test there should be at least 80% survival of control embryos and 70% survival of control organisms overall; and

- If previously unaffected fish are adversely affected near the end of the test, the test should be continued for a specific period of time.

4.5 SUPPORTING TABLES

TABLE 4.5-1 --SPECIES OF "HEAVY METALS" POTENTIALLY TOXIC TO BIOLOGICAL SYSTEMS

	Toxics EPA 1981[a]	Mine/Smelter EPA 1981[b]	Cornish 1984[c]	Torrey 1978[d]	Phillips 1982[e]	Hydrometrics 1983[e,f]	Newman 1980[g]
Al			•				
Ag							
As	•	•	•	•	•	•	•
Ba				•			•
Be	•						•
Bo	•						•
Cd	•	•	•	•	•	•	•
Cl				•			
Cr	•	•		•			•
Co	•	•					
Cu	•			•	•	•	
Fe				•		•	•
Hg	•	•		•	•	•	•
In			•	•		•	•
Mo							•
Ni	•			•			•
P							•
Pb	•	•	•	•	•	•	•
Sb	•						
Se	•			•			•
Si							
Sn	•	•					
V	•						•
Zn			•	•	•	•	•

Notes:

[a] Elements listed as potentially toxic
[b] Elements listed as common from mining and smelting operations.
[c] Elements of concern listed by Cornish (1984) for a soil study around the Washoe Smelter in Anaconda, MT.
[d] Listed potentially toxic.
[e] Elements tested for in fish tissue of the Upper Clark Fork River.
[f] Water quality measurements of Silver Bow Creek.
[g] Listed as having an affect on wildlife.

TABLE 4.5-2 --DOCUMENTED RESPONSES OF BIRDS AND MAMMALS (DOMESTIC AND LABORATORY ANIMALS AND WILDLIFE) TO ACUTE AND CHRONIC EXPOSURE TO SELECTED AIR EMISSIONS

Responses	Selected Air Pollutants															
	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Selenium	Vanadium	Zinc
Changes in Population Numbers	•				•											
Changes in Blood Chemistry or Physiology	•		•		•			•			•	•			•	
Changes in Cellular Enzymes	•		○				•							•		•
Changes in External Appearance	•	•						•			•		•			
Change in Population Distribution																
Change in in Death Rate (in free living animals)	•		•	•	•			•								
Change in Birth Rate	•							•								
Change in Growth Rate			•					•								
Change in Generic Resistance																
Abnormal Behavior	•	•	•	•		•		•	•	•	•		•	•	•	•
Physiological Changes Observed in Autopsy and Historical Analysis	•				•			•	•			•	•	•	•	•
Lowered Resistance to Natural Environmental Stress	•															
Residue Accumulation in Body Tissues	•		•	•	•	•	•	•	•	•	•		•	•	•	•
Tetragenic, Mutagenic, or Carcinogenic		•	•		•	•						•		•		

Source: Newman 1980.

TABLE 4.5-3.--POTENTIAL FOR BIOACCUMULATION OF TOXIC TRACE ELEMENTS IN MAMMALS, BIRDS, AND FISH

Element	Potential for Bioaccumulation[a]	Warm Springs Ponds Interest
Antimony	Low	
Arsenic	Moderate	High
Beryllium	Low	
Boron	Low	
Cadmium	High	High
Chromium	Moderate	Moderate
Cobalt	Low	
Copper	High	High
Lead	High	High
Mercury	High	Low
Nickel	Moderate	Moderate
Selenium	Moderate	Moderate
Tin	Moderate	
Vanadium	Low	

Notes:

[a] Source: EPA 1981.

TABLE 4.5-4.-- AVIAN BODY TISSUE RECOMMENDED FOR BIOLOGICAL MONITORING OF "HEAVY METAL" EXPOSURE

Element[a]	Tissue Type				
	Feather	Liver	Kidney	Muscle	Bone
Aluminum	I	I	I	I	I
Arsenic	G	G	I	I	I
Cadmium	P	E	E	I	I
Chromium	I	I	I	I	I
Copper	G	G	I	I	I
Lead	E	I	I	I	E
Mercury	E	E	G	I	I
Nickel	I	I	G	I	I
Selenium	G	G	I	I	I
Zinc	I	I	I	I	I

Notes:

[a] Of interest to Silver Bow Creek Remedial Investigation

[b] Source: EPA 1981;
P = Poor
G = Good
E = Excellent
I = Insufficient Data

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS

PART A. MILE-HIGH SOIL CONSERVATION DISTRICT (SILVER BOW COUNTY)

Landowner(s) Name(s)	Address/Phone No.	Comments
Arms, Benton & Joyce	W of Ramsay/782-7149	Have irrigated land in T4NR9W32, subject possibly to aerial deposition of smelter contaminants.
Christian, Calvin J.	Unidentifiable at present	Owns land in both T3NR9W16 and T3NR10W2.
Clayton, George	In c/o Frank Tonkin 2610 Kossuth, Butte	Appears to own land encompassing Silver Bow Creek in T3NR10W12.
Craddock, William E. Hensler, Wilbur J.	W of Ramsay/782-7192	Same situation as for Arms' above. Owns land in T3NR9W16, adjacent to Silver Bow Creek.
Konda, Walter and Marion	W of Ramsay/723-7003	Have a sub-irrigated hay pasture in T3NR9W16, subject possibly to aerial deposition of smelter contaminants.
Miles, Nancy E.	Unidentifiable at present	Owns land in the vicinity of Silver Bow Creek in T3NR9W16.
Peterson, William N., Geraldine et al.	Star Route East, Anaconda	Own land in Sections 2 and 12 of T3NR10W.
Spangler Ranch, Inc., Hazel L. Spangler	SE. of Opportunity/ 797-3231	A major land owner in the area (e.g., T4NR9W31) who has fields containing excessive levels of various "heavy metals."
Ueland, Don	Silver Bow/723-7340	Owns land adjacent to Silver Bow Creek in T3NR9W16.

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES)

Landowner(s) Name(s)	Address/Phone No.	Comments
Atkins, Mrs. Dale	S of Deer Lodge/846-1864	Either pumps of diverts water from the Clark Fork River.
Beck, Albert	681 Greenhouse Rd./ 846-1795	Ditto.
Beck, Charles E.	236 Greenhouse Rd./ 846-2385	Agent for the West Side Ditch Irrigation Group.
Beck, Don W.	Galen-Warm Springs/ 693-2267	May divert water from the River and uses groundwater for irrigation.
Beck, Melvin	500 Greenhouse Rd./ 846-2734	Pumps water from the River, and also serves as agent for the Green Acres Group.
Beck, Pete	376 Greenhouse Rd./ 846-3601	Uses water from the West Side Ditch.
Beck, Tom	651 Greenhouse Rd./ 846-2452	Pumps water from the River, and serves also as a Powell County Commissioner.
Bucher, Jack	Jens/288-3480	None
Dutton Ranch	Gold Creek/288-3411	None
Edge, Keith and Peggy	S. of Deer Lodge/846-3802	None
Eliason, Leonard	731 Gem Back Rd./846-2691	Pumps and diverts water from the River.

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Address/Phone No.	Comments
Fergeson, Harry (M.D.)	Opportunity/797-3707	Concerned about tailings contamination of Silver Bow and Mill Creeks.
FFA Farm, Powell Co. High School	Missouri and Claggett/ 846-2757	Utilize groundwater, and possibly divert surface (River) water.
Forsen, Dick	S of Deer Lodge/846-1449	Utilizes both groundwater and diverted River water; has expressed concern about tailings deposited on his land.
Fries, Orville	110 Eastside Rd./846-3514	Utilizes at least groundwater for irrigation purposes.
Gilman, Marlin	W. of Garrison/846-1514	Diverts water from the River, and serves on the ASCS Advisory Committee.
Hogan, Sam	Gold Creek/288-3491	None
Hollenback, John	Gold Creek/288-3382	Serves on the SCS Conservation District Advisory Board.
Indreland, R. E.	602 Milwaukee/846-2456	Very familiar with the history of irrigation in the Deer Lodge Valley.
Jacobson, Bud and Edna	1120 Yellowstone Trail/ 693-2379	Contact at the First Security Bank/ 846-2300 (Deer Lodge).
Johnson, Allen P.	481 North Frontage Rd./ 846-1832	Diverts water from the River in the vicinity of Grant Kohrs Ranch; serves as the agent for the Kohrs-Manning Irrigation Group.

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Address/Phone No.	Comments
Johnson, Bill	E. of Deer Lodge/846-1603	None
Johnson, Eric	E. of Galen/693-2312	Pumps and diverts water from the River to irrigate large tracts of land.
Kelly, Jack Jr.	791 Yellowstone Trail/ 846-3269	Mrs. (Tony) Kelly is active in smelter-related impact assessment concerns, and is a good source of information on this subject matter.
Kelly, Ron	350 Greenhouse Rd./ 846-3825	Alfalfa crop is analyzed (at least for protein content) each year; can be reached also at the First Security Bank/846-2300 (Deer Lodge).
Kellicut, Skip	E. of Racetrack-Warm Springs/693-2327	Has submitted soil samples to MSU for arsenic analysis; can also be contacted at the First Security Bank/846-2300.
Lampert, Hans	200 East Side Rd./ 846-1786	Owns large tracts of bottom lands, and has expressed concern over tailings contamination of crops.
Launderville, Gary J.	971 Race Track Rd., Warm Springs/693-2365	Pumps water from recently installed wells.
Little, David	Jens/288-3832	None

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Address/Phone No.	Comments
Long, Huey	900 Milwaukee Av./ 846-3765	Concerned with soil/crop contamination by tailings; can be reached also at the USDA SCS Office/846-1703 (Deer Lodge).
Lowery, Alfred & Mary	430 Greenhouse Rd./ 846-2781	May have affected lands (from past irrigation with contaminated River water).
Montana Department of Fish, Wildlife, and Parks (MDFWP)	Contact Bob Greene/ 693-2262	The MDFWP uses water from Warm Springs Settling Pond No. 3 to irrigate several tracts of barley (to the east of the ponds) for waterfowl feeding.
Mosier, Bill Jr.	371 Freeze Out Lane/ 846-2828	A major consumer of water from the Kohrs-Manning Ditch; also is a Supervisor for the Deer Lodge Valley Conservation District.
Murphy, William	471 Warm Springs Creek Rd./846-2625	Pumps water from the River; serves also on the ASCS Advisory Committee
Olsen, Lars	N of Deer Lodge/846-2643	Probably diverts water from the River.
Opportunity Community Pasture	Contact Don Hewitt/ 797-3704	Ground water is utilized by cattle; Dave Streufert, County Extension Agent (Deer Lodge) has taken soil samples in the area.
Perkins, Jack	1472 Perkins Rd./846-1365	Some of his properties may have received aerial deposition of "heavy metals" emitted from the smelter stack. Serves as a Supervisor for the Deer Lodge Valley Conservation District.

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Address/Phone No.	Comments
Peterson, Wendell	Warm Springs/693-2329	Not certain whether waters are pumped or diverted from the River.
Pilgeram, Zane	Gold Creek/288-3356	Either diverting or pumping large amounts of water in the vicinity of Gold Creek; tailings are present on his property.
Probert, Ray	S. of Deer Lodge/ 846-3138	Possibly diverts water from the West Side Ditch.
Ragsdale, Audrey	641 Gem Back Rd./846-2480	Owns an inactive farm having considerable amount of tailings on the property; might have suffered contamination problems historically.
Reistad, Melvin E.	291 Greenhouse Rd./ 846-1377	Either diverts water from the River or uses ground water for crop irrigation purposes.
Rock Creek Cattle Co.	Contact Don Davis, Mgr./ 846-2555 (N. of Deer Lodge)	Own considerable tracts of land adjacent to the River; have diverted surface waters and may be pumping from River also.
Seitz, Greg & Pat	Willow Glen/797-3529	Have lost cattle due to drinking from arsenic-contaminated storm-runoff waters.
Spangler, Hazel	SE. of Opportunity/ 797-3231	Some of her properties may have received aerial deposition of "heavy metals" emitted historically from the smelter stack.
Tamcke, Don	SW. of Deer Lodge/846-1504	Ditto.

TABLE 4.5-5.--POTENTIALLY AFFECTED LANDOWNERS PRESENT WITHIN THE MILE-HIGH AND DEER LODGE VALLEY SOIL CONSERVATION DISTRICTS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Address/Phone No.	Comments
Tammen, Gerald	SE. of Warm Springs/ 693-2254	Owns land adjacent to the AMC (Warm Springs) settling ponds.
Vanisko, John	NW. of Galen/693-2360	Director of the Montana Association of Conservation Districts.

Sources: Landowner plat books in Butte and Anaconda City-County Courthouses plus personal interviews of Ms. Sherry Dutton and Mr. Bob Tribelhorn, USDA SCS (Deer Lodge).

TABLE 4.5-6.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS IRRIGATION WATER SUPPLIES*

PART A. SELECTED TRACE ELEMENTS POTENTIALLY PHYTOTOXIC TO CROP SPECIES.

Element	Irrigation Condition: Waters Used Continuously on All Soils (ppm)	Irrigation Condition: For Short-Term Use On Fine-Textured Soils Only (ppm)	Comments
Aluminum (Al)	1.0	20.0	Toxicity concerns of little consequence at para-neutral pH, even in sandy-textured soils.
Arsenic (As)	1.0	10.0	Excessive levels of soluble arsenic can reduce crop yields; main symptom of toxicosis is the distruction of chlorophyll in the foliage.
Beryllium (Be)	0.5	1.0	Of particular concern under acid pH conditions.
Boron (B)	0.70	2.0	Concentrations in the 0.5 to 0.7 ppm range, as measured in saturation paste extract, will protect B-sensitive deciduous fruit crops. Concentrations of $\leq$ 2.0 ppm are suitable for such semi-tolerant crops as oats, barley and wheat. Alfalfa, a B-tolerant species, can utilize waters containing 3.5 to 4.0 ppm concentrations of B. Tolerance criteria are influenced by soil type, drainage, and climate conditions, plus quantity of irrigation waters applied.
Cadmium (Cd)	0.005	0.05	Presumes that Cd behaves similarly to zinc in its uptake by plants and interaction with various (other) soil constituents. Higher levels of Cd can probably be tolerated via appropriate soil management practices.

TABLE 4.5-6.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS IRRIGATION WATER SUPPLIES (CONTINUED)

PART A. SELECTED TRACE ELEMENTS POTENTIALLY PHYTOTOXIC TO CROP SPECIES (CONTINUED).

Element	Irrigation Condition: Waters Used Continuously on All Soils (ppm)	Irrigation Condition: For Short-Term Use On Fine Textured Soils Only (ppm)	Comments
Copper (Cu)	0.2	5.0	Copper retention in soil appears to be correlated more with organic matter content and soil alkalinity than with its clay content; organic matter appears to be more effective than carbonates in retaining copper ions.
Lead (Pb)	5.0	20.0	Although nutrient culture studies have reported toxic responses at concentrations of 1 ppm, considerably higher doses are required to induce injury in most plant species. As even sandy textured soils can absorb some Pb, the 5.0 ppm recommended level appears to be reasonable
Molybdenum (Mo)	0.005	0.05	In nutrient solution and soil solution measurements, 0.01 ppm Mo produced legumes containing ~5mg/kg; this tissue concentration is commonly accepted as the upper limit for safe feeding to cattle. An upper limit of 0.05 ppm is recommended when irrigation water is added to acid soils having a large capacity to immobilize this element.

TABLE 4.5-6.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS IRRIGATION WATER SUPPLIES (CONTINUED)

PART A. SELECTED TRACE ELEMENTS POTENTIALLY PHYTOTOXIC TO CROP SPECIES (CONTINUED).

Element	Irrigation Condition: Waters Used Continuously on All Soils (ppm)	Irrigation Condition: For Short-Term Use On Fine Textured Soils Only (ppm)	Comments
Selenium (Se)	0.05	0.05	Presumes that 0.05 ppm in solution translates to toxic dosages in livestock of 4 to 5 mg/kg-day. Thus, this irrigation "standard" is complicated by such factors as plant species and age, season of year, and concentrations of soluble selenium compounds and sulfate ion within the rooting zone. Recommended guidelines as high as 0.2 ppm (long-term use) and 0.5 ppm (short-term use) exist in the published literature.
Zinc (Zn)	5.0	10.0	A general guideline of 5.0 ppm appears reasonable, as Zn is strongly bound to even coarse-textured soils at this concentration. Concentrations $\geq$ 10 ppm can produce toxic symptoms in Zn-tolerant species (e.g., oats).

TABLE 4.5-6.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS IRRIGATION WATER SUPPLIES (CONTINUED)

PART B. OTHER PHYSIOCHEMICAL FACTORS POTENTIALLY PHYTOTOXIC TO CROP SPECIES.

Factor	Tolerable Range	Preferred Range	Comments
Acidity-Alkalinity			
• bicarbonate ion	1.25-2.5 meq/l	$\leq$1.25 meq/l	Expressed as "residual sodium carbonate" concentration (RSC), and is defined as follows: RSC = $[CO_3^{-2} + HCO_3^{-}] - [Ca^{+2} + Mg^{+2}]$.
• pH	4.5-9.0 std. units	5.5-8.0 std. units	Useful as a general indicator of nutrient plant-availability; little direct biological significance can be attached to this parameter.
Salinity-Related			
• electrical conductivity	<0.75-7.5 dsm/cm @25°C.	<0.75-1.50 dsm/cm @25°C.	As measured in the irrigation water, not in the soil solution extract.
• sodium adsorption ratio (SAR)	8-15, dimensionless	$\leq$8	SAR defined as follows: $[Na^{+}]/\sqrt{[Ca+Mg]/2}$; as values given are for the soil solution, the guidelines for irrigation waters should be fractions of the stated values, in order to compensate for sodium concentration by evaporation.
• exchangeable sodium percentage (ESP)	10-18, dimensionless	1-10	Equilibrium ESP value in soil solution is determined via extrapolation from the SAR value calculated for the particular irrigation water sources.

TABLE 4.5-6.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS IRRIGATION WATER SUPPLIES (CONTINUED)

PART B. OTHER PHYSIOCHEMICAL FACTORS POTENTIALLY PHYTOTOXIC TO CROP SPECIES (CONTINUED)

Factor	Tolerable Range	Preferred Range	Comments
Salinity-Related (Continued)			
• total dissolved solids (TDS)	<500-5000 ppm	<500-1000 ppm	Useful as a general indicator of potential salinity hazard; values <500 mg/l can be problematic if there is a high water table.
Sediment and Suspended Solids (TSS)	Unquantified	Unquantified	The total suspended solids can interfer with conveyance of water within irrigation ditches, and clog or accelerate wear on pump-pipe system appliances. Once deposited (as a film) on leaf surfaces, the solids can reduce photosynthetic activity (thereby reducing growth) and can add to the "heavy metal" burden via adsorption onto the leaves, etc.
Temperature	Uncertain (35-105°F?)	Uncertain (55-85°F.?)	Excessively cold or hot temperatures can adversely affect crop growth rates and yields, mainly by affecting soil temperatures.

Sources: USDI Federal Water Pollution Control Administration 1968; McFee and Wolf 1963; Richards et al. 1954.

TABLE 4.5-7.--ESTIMATED RANGE (FROM LITERATURE SEARCH) OF VALUES FOR SELECTED PARAMETERS WITHIN THE SURFACE FOOT OF UNCULTIVATED FLOODPLAIN-LOW TERRACE SOILS, DEER LODGE VALLEY, MONTANA

Category	Parameter[a]	Expected Range	Elevated Condition
Non-elemental, but plant nutrient-related	pH	6.0-8.0	<5.0, >8.5
	Redox potential (E_h)	250-500	<100, >600
Vascular plant macro-nutrients[b]	Calcium (Ca)	65-850	>10000
	Magnesium (Mg)	15-140	>2000
	Total Kjeldahl Nitrogen (N)	0.06-0.6	>1.5
	Phosphorus (HPO_4^{-2})	0.2-2.0	>3.0
	Potassium (K)	40-155	>200
	Sulfur (SO_4^{-2})	2-100	>200
Vascular plant micro-nutrients[b]	Boron (B)	0.5-4.5	>4.5
	Cobalt (Co)	0.01-0.15	>0.3
	Copper (Cu)	0.1-5.0	>10.0
	Iron (Fe)	5-15	>25
	Manganese (Mn)	0.2-20	>35
	Molybdenum (Mo)	0.01-0.30	>1.0
	Zinc (Zn)	0.05-4.5	>10
Potentially biohazardous elements (e.g., to vascular plants)[b]	Aluminum (Al)	200-2000	>3500
	Arsenic (As)	0.02-0.20	>0.40
	Cadmium (Cd)	0.005-0.15	>0.20
	Chromium (Cr)	0.001-0.01	>0.20
	Fluorine (F^-)	0.05-2.50	>2.50
	Lead (Pb)	0.01-3.5	>5.0
	Mercury (Hg)	0.001-0.015	>0.025
	Nickel (Ni)	0.02-0.50	>0.75
	Selenium (Se)	0.005-0.50	>0.50
	Vanadium (V)	0.01-0.30	>1.0

Notes: a) pH reported in standard units, E_h in millivolts (corrected to 25°C), total micro-Kjeldahl nitrogen in weight-percent, and all other parameters in µg/gm (ppm) concentrations.

b) "Plant-available" estimates from -2 mm mesh soil fraction, using sodium diamine pentacetate solution or in ammonium acetate (pH = 6) solution.

Sources: Bohn et al. 1979, Brady 1974, Berry and Wallace 1974, Chaney 1983, Dvorak et al. 1978, Garrels and Christ 1965, Lewis et al., 1978, Lisk 1972, Mortvedt et al., 1972, MultiTech 1984.

TABLE 4.5-8.--ESTIMATED BACKGROUND AND ELEVATED ELEMENTAL CONCENTRATIONS IN NATIVE AND CULTIVATED VEGETATION PRESENT WITHIN THE STUDY AREA

Element	"Background"[a]	"Elevated"[b]
Arsenic (As)	0.05 - 1.5	> 2.5
Beryllium (Be)	0.01 - 0.10	> 0.25
Boron (B)	3 - 8	> 50
Calcium (Ca)	1800 - 36,000	> 45,000
Cadmium (Cd)	0.01 - 0.75	> 3.5
Chromium (Cr)	0.05 - 0.5	> 2.0
Cobalt (Co)	0.02 - 0.35	> 2.5
Copper (Cu)	8 - 16	> 20
Fluorine (F)	1.5 - 20	> 45
Iron (Fe)	80 - 240	> 350
Lead (Pb)	0.5 - 15	> 45
Magnesium (Mg)	1200 - 2000	> 4,000
Manganese (Mn)	20 - 50	> 500
Mercury (Hg)	0.001- 0.025	> 0.05
Molybdenum (Mo)	0.5 - 2.0	> 4
Nickel (Ni)	0.1 - 4.0	> 5
Nitrogen (N)	9600 - 19,200	--[c]
Phosphorous (P)	500 - 3000	--[c]
Potassium (K)	7500 - 25,000	--[c]
Selenium (Se)	0.005-0.5	> 3
Sulfur (S)	1100 - 2800	> 3,500
Vanadium (V)	0.02 - 0.85	> 2.5
Zinc (Zn)	25 - 50	> 150

Note: a) All concentrations given in µg/gm (ppm), air-dried (<40°C) weight for aerial portions of washed plant material approaching maturity, but not senescent. No particular elemental "accumulator" species are presumed to exist within the study area.

b) "Elevated" levels do not represent necessarily concentrations toxic to animals consuming them; rather, they represent concentrations judged to be unexpected, given the present understanding of the area's soils, geology, climate, etc.

c) Available data was insufficient to prepare these estimates.

Sources: Baker and Chesnin 1975, Chaney 1983, Chapman 1973, Dvorak et al. 1978, MultiTech 1984a, Siegel 1974, Underwood 1977.

TABLE 4.5-9.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS LIVESTOCK WATERING SUPPLIES

PART A. SELECTED TRACE ELEMENTS

Element	Recommended Concentration (ppm)	Comments
Antimony (Sb)	$\leq$300	Based on safe intake of ~11.4 gms. of antimony potassium tartrate per day in dairy cattle, consuming 10 gallons of water per day.
Arsenic (As)	$\leq$0.05	Safe upper limit of concentration may be 0.2 ppm in drinking water.
Beryllium (Be)	$\leq$6000	Derived from calculations indicating no ill effects to cows drinking 250 gallons of water per day, containing this concentration of Be.
Boron (B)	$\leq$2	To avoid toxicosis in lambs. The upper safe limit is probably in the 5-10 ppm range for other livestock species.
Cadmium (Cd)	$\leq$0.01	Safe upper limit of concentration probably varies from 0.05 to 0.50 ppm., depending upon species, age of animal, etc.
Chromium (Cr^{+6})	$\leq$0.05	Upper safe limit for total Cr may approach 5.0 ppm in beef cattle.
Cobalt (Co)	$\leq$1.0	Short-term uptake of <20 ppm appears tolerable in cattle, i.e., for period of less than 30 days.
Copper (Cu)	$\leq$0.05	Although the upper safe limit could approach 2.5 to 5 ppm, the adverse taste of such waters would prevent (probably) the consumption of toxic amounts of Cu.
Fluorine (F^-)	$\leq$2.0	Concentrations ranging from 5 to 10 ppm can produce mottled teeth in sheep and cattle.

TABLE 4.5-9.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS LIVESTOCK WATERING SUPPLIES (CONTINUED)

PART A. SELECTED TRACE ELEMENTS (CONTINUED)

Element	Recommended Concentration (ppm)	Comments
Iron (Fe)	≤1.0?	Reports on direct-toxicity resulting from iron (in water) are not available. However, it has been suggested that intake of water (by livestock) may be inhibited if it contains excessive amounts of Fe. The stated criterion represents the 1958 World Health Organization's suggested value for "excessive" limit for this metal.
Lead (Pb)	≤0.05	Upper safe limit probably varies from 0.1 to 0.5 ppm, depending upon the species and age of the particular animal. There is a considerable difference in the relative toxicities of various compounds of lead.
Manganese (Mn)	≤1?	The available data indicates that Mn is not very toxic to livestock; however, concentrations as low as 1 ppm can be harmful to legumes. The stated criterion would thus protect irrigated crops and not be particularly excessive for livestock consumption either.
Mercury (Hg)	<0.010	Apparently, this criterion is based on mg/l of methyl-Hg.
Molybdenum (Mo)	≤1.0	Upper safe limit probably approaches 5 ppm, especially when Cu levels are adequate.
Nickel (Ni)	≤1.0	Upper safe limit probably approaches 5 ppm, especially if Mo is adequate and Se is not excessive.

TABLE 4.5-9.--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS LIVESTOCK WATERING SUPPLIES (CONTINUED)

PART A. SELECTED TRACE ELEMENTS (CONTINUED)

Element	Recommended Concentration (ppm)	Comments
Selenium (Se)	$\leq$0.25	Water containing the stated level of Se may contribute to selenium toxicosis; as the Se content of food is usually considered the more important factor, toxicity is best evaluated using a tolerable dose factor of 4 mg/kg-day.
Vanadium (V)	$\leq$0.5	Upper safe limit probably approaches 5 ppm, especially if Se levels are not excessive.
Zinc (Zn)	$\leq$25.0	Upper level for safe consumption of Zn could approach 50 to 100 ppm. However, such concentrations would adversely affect all but the most Zn-tolerant plant species. Chronic constipation has been observed in dairy cattle consuming waters containing $\leq$10 ppm Zn.

PART B. OTHER PARAMETERS OF INTEREST

Anions		
• Chloride (Cl^-)	<1500 ppm	Judged to be safe for cattle, sheep, swine, and poultry species.
• Nitrate (NO_3^-)	$\leq$150 ppm	Excessive concentrations of NO_3^- can result in depressed weight gains, fetal abortions, or methemoglobinemia.
• Nitrite (NO_2^-)	$\leq$10 ppm	Ditto.
• Sulfate (SO_4^{-2})	<1000	Values twice this concentration can cause progressive weakening and death in cattle.

TABLE 4.5-9 .--PERTINENT WATER QUALITY EVALUATION CRITERIA FOR USE AS LIVESTOCK WATERING SUPPLIES (CONTINUED)

PART B. OTHER PARAMETERS OF INTEREST (CONTINUED)

Element	Recommended Concentration (ppm)	Comments
Cations		
• Magnesium (Mg^{+2})	<2050 ppm	Magnesium sulfate levels exceeding the criterion produce laxative effects.
• Sodium (Na^{+})	<2000 ppm	A tentative value, as considerable differences exist (in sensitivity) between various livestock species.
Miscellaneous		
• pH	6.0 - 8.5 std. units	More of a "welfare" than strictly health-related criterion, although values lying outside the stated range probably indicate trace element deficiency or toxicity problems.
• Salinity (total dissolved solids)	1000-6000 ppm	Horses are most sensitive, beef and dairy cattle have moderate sensitivity while sheep are relatively tolerant to salinity. Values >10,000 ppm will probably affect (adversely) the economics of production.

Note: a) The specific values are advisory only, as antagonistic or synergistic effects occurring between various combinations of potential toxicants are difficult to quantify, and--in many cases--are presently unknown.

Sources: Dyer and Johnson 1976, McKee and Wolf 1963, Shirley et al. 1974, USDI Federal Water Pollution Control Administration 1968.

TABLE 4.5-10.--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA

PART A. TISSUE LEVELS

Element	Livestock Species	Diet Type[b]	Hair	Blood, Whole	Blood, Serum	Kidney, Renal Cortex	Liver	Urine	Milk
Arsenic	Cattle	Normal	0.5-3.0	0.03	U	0.15-0.40	0.03-0.40	0.5	0.03-0.06
		High	U[c]	0.06	U	1.5-5.0	1.0-50	U	U
		Toxic	-	-	-	-	-	-	-
		• acute	>15	0.17-1.0	U	3.5-38	2.0-15	2-14	0.34-0.47
		• chronic	10	U	U	5.0-53	7.0-70	U	U

Comments

Arsenic may act as an essential trace element, but no deficiencies have been identified (as of 1981). Arsenite salts are more toxic than arsenate salts. Cattle can develop a tolerance to As if fed at sublethal doses over a period of time, and will search out high As forage for preferred consumption.

Horses	Normal	0.0-0.3	U	U	<0.40	<0.4	<0.4	U
	High	3.9-4.2	U	U	1.0-5.0	1.0-3.0	U	U
	Toxic	U	U	U	7.0-15	7.0-15	10.0	U
Sheep	Normal	U	U	U	0.1-0.3	0.03-0.20	U	U
	High	U	0.04-0.8	U	U	4-8	U	U
	Toxic	U	5.0	U	10-40	10-50	100-150	U

Comments

Sheep are slightly more tolerant of As than cattle. Sheep do not find As distasteful, and will selectively graze contaminated pastures.

TABLE 4.5-10.--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART A. TISSUE LEVELS (CONTINUED)

Element	Livestock Species	Diet Type[b]	Hair	Blood, Whole	Blood, Serum	Kidney, Renal Cortex	Liver	Urine	Milk
Cadmium	Cattle	Normal	0.04-0.60	0.004-0.04	U	0.05-1.5	0.02-1.0	U	0.001-0.03
		High	0.67-16.0	U	U	5.0	1.4-2.0	U	0.010-0.03
		Toxic	40-100	-	-	-	-	-	-
		• acute	U	U	U	>200	50	U	U
		• chronic	U	0.04	U	100-250	50-160	U	U
		Comments							
		Cadmium accumulates in liver and kidney as a function of age. Cd is antagonistic to Cu, Co, Fe, Mn, Se, and Zn metabolisms. Excess Cd reduces the toxic effect(s) of Pb, while Cd toxicity increases (in severity) if dietary Ca is low.							
	Horses	Normal	~0.3	U	U	0.05-10.0	0.01-5.0	U	U
		High	1.0-3.0	U	U	4.2-23.0	22.0	U	U
		Toxic	9.0?	U	U	>200	U	U	U
	Sheep	Normal	0.55-1.22	0.02-0.20	U	0.14-0.48	0.04-1.40	U	U
		High	U	U	U	4.0	2.0-20	U	U
		Toxic	>20	0.10-0.20	U	50-400	50-600	U	U

TABLE 4.5-10. --TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART A. TISSUE LEVELS (CONTINUED)

Element	Livestock Species	Diet Type[b]	Hair	Blood, Whole	Blood, Serum	Kidney, Renal Cortex	Liver	Urine	Milk
Copper	Cattle	Normal	6.7-15	0.93	0.08-1.50	4.0-6.0	25-150	U	0.05-0.60
		High	U[c]	U	2.50-4.0	U	250	U	U
		Toxic	U	U	4.0-11.0	10.0-15.0	250-700	U	U
		Comments: Plasma or serum levels better indicate Cu status than do whole blood levels. High dietary levels of protein, Fe, Mo, and Zn reduce copper toxicity.							
	Horses	Normal	U	U	1.0-1.70	7.3-9.3	4.0-7.5	U	0.2-1.0
		High	U	U	U	30-40	1000-1500	U	U
		Toxic	U	U	U	U	U	U	U
	Sheep	Normal	6.0-15.0	U	0.80-2.0	4.0-5.0	25-100	U	0.2-0.4
		High	U	U	1.5-5.0	U	100-300	U	U
		Toxic	U	10-14	3.3-20	18.0-120	250-1000	U	U
		Comments: Confinement-housed sheep seem to have a lower Cu requirement than free-ranging sheep.							

TABLE 4.5-10. --TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART A. TISSUE LEVELS (CONTINUED)

Element	Livestock Species	Diet Type[b]	Hair	Blood, Whole	Blood, Serum	Kidney, Renal Cortex	Liver	Urine	Milk
Lead	Cattle	Normal	0.5-5.0	0.02-0.2	U	0.2-2.0	0.1-1.0	U	0.002-0.04
		High	60-90	0.30-0.40	U	3-20	2-10	U	U
		Toxic	10-100	0.35-32.0	U	10-700	5-300	U	0.10-0.25
			Comments						
			Confirmation of lead toxicosis should be based on analytical data from both kidney and liver tissues.						
	Horses	Normal	1-3	0.04-0.25	U	0.5	0.5	0.04-0.2	0.006-.013
		High	3-10	0.30-0.60	U	3.0-5.0	3-5	U	<0.10
		Toxic	12-35	-	-	-	-	0.5-5.0	0.28-0.54
		• acute	U	0.60-2.50	U	20-200	10-500	U	U
		• chronic	U	0.33-0.50	U	5-140	4-50	U	U
			Comments						
			Blood levels are not good indicators of Pb toxicosis. Cu, Fe, and Se metabolisms are adversely affected by Pb, while Pb toxicity may be enhanced by Zn. Pb toxicosis is common due to ingestion of soil along with plant material.						
	Sheep	Normal	4.0-7.0	0.02-0.25	U	0.1-0.80	.05-0.80	U	U
		High	12-18	0.70-0.90	U	5-100	5-25	U	U
		Toxic	≥25	1-5	U	5-200	10-100	U	U
			Comments						
			Pb reduces copper storage and interfers with Se metabolism. Pb poisoning of sheep is not common.						

TABLE 4.5-10. --TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART A. TISSUE LEVELS (CONTINUED)

Element	Livestock Species	Diet Type[b]	Hair	Blood, Whole	Blood, Serum	Kidney, Renal Cortex	Liver	Urine	Milk
Molybdenum	Cattle	Normal	0.01-0.56	0.01-0.05	0.05-1.12	0.22-0.57	0.57-1.14	U	.018-0.12
		Toxic (Cu deficient)	1.5-2.6	0.10-0.47	6.5-11.1	1.15-2.60	1.4-100	U	U

Comments

Plants growing in alkaline or organic soils often have unsuitable Cu/Mo ratios (i.e., <2:1). Dietary Mo above 10 ppm can cause toxicity, regardless of Cu intake.

Zinc	Cattle	Normal	100-150	U	0.7-1.4	18	25-50	U	2.3-5.1
		High	U	U	U	U	U	U	U
		Toxic	U	U	5.2-7.5	130-180	>500	U	8.4
	Horses	Normal	~190	2.0-5.0	U	20-27	40-80	U	2-4
		High	200-300	U	U	U	U	U	U
		Toxic	>300	6-15	U	295-580	1300-1900	U	U
	Sheep	Normal	70-130	U	0.8-1.50	12-30	30-75	U	2-5
		High	U	U	4-5	1000	400	U	U
		Toxic	U	U	30-50	U	U	U	U

Comments

Plasma or serum Zn levels are affected by infection, trauma, low protein intake, and pregnancy. High Zn levels may protect against Cu toxicity.

TABLE 4.5-10. --TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART B. DIETARY AND DOSAGE INFORMATION

Element	Livestock Species	Diet Type	Concentration (Range) in Diet (ppm)[d]	Toxic Dosage Acute (mg/kg)	Toxic Dosage Chronic (mg/kg-day)
Arsenic	Cattle	Normal	~0.25	N/A[e]	N/A[e]
		Toxic	>350	750	7.5-10
	Horses	Normal	U	N/A	N/A
		Toxic	>200	~650	3.3-5.5
	Sheep	Normal	U	N/A	N/A
		Toxic	10-1000	11-220	U
Cadmium	Cattle	Normal	0.01-0.5	N/A	N/A
		High	5.0	N/A	N/A
		Toxic	-	-	-
		• acute	2000-3000	U	N/A
		• chronic	50-500	N/A	U(>10?)
	Horses	Normal	U	N/A	N/A
		Toxic	U	"	U
	Sheep	Normal	<0.5	N/A	N/A
		High	5.0	N/A	N/A
		Toxic	50-500	U	U
Copper	Cattle	Normal	10-50	N/A	N/A
		Toxic	>115	40-800	~3.5
	Horses	Normal	U	N/A	N/A
		Toxic	800	U	U
	Sheep	Normal	5-10	N/A	N/A
		Toxic	>10	20-50	>3

TABLE 9.5-10.--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART B. DIETARY AND DOSAGE INFORMATION (CONTINUED)

Element	Livestock Species	Diet Type	Concentration (Range) in Diet (ppm)[d]	Toxic Dosage Acute (mg/kg)	Toxic Dosage Chronic (mg/kg-day)
Lead	Cattle	Normal	5-15	N/A[e]	N/A[e]
		Toxic	5-300	200-800	3-5
	Horses	Normal	1-30	N/A	N/A
		Toxic	80-1000	900	2.4-7
	Sheep	Normal	<1-3	N/A	N/A
		Toxic	5-300	20-80	0.3-3
Molybdenum	Cattle	Normal	0.5-3.5	N/A	N/A
		Toxic	5-6 (Cu=8-11) (Sheep: 10-12, where Cu=8-11)	<2:1 Cu:Mo	2.1-3.1 (Cu:M
Zinc	Cattle	Normal	50-100	N/A	N/A
		High	1000-5000	N/A	N/A
		Toxic	>5000	20000	U
	Horses	Normal	40-100	N/A	N/A
		High	U	N/A	N/A
		Toxic	3600	>90	<60
	Sheep	Normal	50-100	N/A	N/A
		High	800-1000	N/A	N/A
		Toxic	2000	180	20

TABLE 4.5-10 .--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART B. DIETARY AND DOSAGE INFORMATION (CONTINUED)

Notes: a) All tissues except hair are expressed on a wet ("fresh") weight ppm basis; hair values are given on a dry weight basis.

b) Diet type defined as follows: "Normal" is used where deficiencies are unknown, and indicates generally accepted background concentrations (of a given element). "High" refers to element levels that are elevated well above normal, but which are not necessarily toxic. "Toxic" is used for those elemental concentrations at which subclinical, clinical, or pathological signs of toxicity would be expected to occur, (Puls 1981).

c) "U" designates a value either unavailable at the time of compiling the literature, or which is presently unknown.

d) Dietary levels are presented on a dry weight basis.

e) "N/A" means not applicable.

Sources: Bartik and Piskac 1981, Clarke et al. 1981, Lewis 1972, Lillie 1972, Parada 1981, Penumarthy et al. 1980, Puls 1981, Underwood 1977.

TABLE 4.5-11.--EVALUATION OF POTENTIAL CHRONIC TRACE ELEMENT TOXICOSIS IN SELECTED LIVESTOCK SPECIES

Livestock Species[a]	Trace Element	Dosage (mg/kg-day) Soil[b]	Food[c]	Water[d]	Total (Body) Burden[e]	Chronic Toxicity[f]
Cattle	As	0.357	0.034	0.008	0.399	7.5-10
	Cu	0.426	0.270	0.078	0.774	~3.5
	Pb	0.154	0.606	0.008	0.768	3-5
Horses	As	0.714	0.042	0.004	0.760	3.3-5.5
	Pb	0.309	0.340	0.004	0.653	2.4-7
Sheep	Cu	2.272	0.640	0.067	2.979	>3
	Pb	0.824	1.440	0.007	2.271	0.3-3

Notes:

a) Assumes average body weights for cattle, horses, and sheep of 450, 500, and 60 kg, respectively, (Radeleff 1970).

b) As, Cu, and Pb total concentrations within the upper few inches of soil are assumed to be 238, 284, and 103 µg/g respectively (Table 3-1, 6-10 miles radial increment, Multi-Tech 1984). Assumes also that cattle, horses, and sheep ingest 10, 15, and 20 percent of their respective total dry matter intake (per day) as soil (Thornton and Abrahams 1981, Egan and O'Cuill 1970, Schmitt et al. 1971).

c) As, Cu, and Pb concentrations in forage are assumed to be elevated, but not necessarily toxic. The respective concentrations (µg/g) are 2.5, 20, and 45 (Table 4.5-10). Average daily consumption of forage for cattle, horses, and sheep assumed to be 6.75, 10, and 2.4 kg, respectively, (Radeleff 1970).

d) As, Cu, and Pb concentrations are assumed to be at the threshold recommended values of 0.05, 0.5, and 0.05 mg/l, respectively (Table 4.5-9). Average daily consumption of water for cattle, horses, and sheep is assumed to be 70, 37, and 8 liters/day, respectively, (Shirley et al. 1974).

e) Represents the summation of the soil, food, and water dosages, per species-element combination.

f) Chronic toxicity values taken from Table 4.5-10.

TABLE 4.5-12.--RE-EVALUATION OF POTENTIAL LIVESTOCK TOXICOSES USING "WORST CASE" ASSUMPTIONS

Livestock Species[a]	Trace Element	Dosage (mg/kg-day) Soil[b]	Food[c]	Water[d]	Total (Body) Burden[e]	Acute Toxicity[f]	Chronic Toxicity[f]
Cattle	As	1.461	0.517	0.008	1.986	750	7.5-10
	Cu	3.356	0.736	0.078	4.170	40-800	~3.5
	Pb	0.848	1.012	0.008	1.868	200-800	3-5
Horses	As	2.922	0.651	0.004	3.577	~650	3.3-5.5
	Pb	1.695	1.275	0.004	2.974	900	2.4-7
Sheep	Cu	17.896	1.744	0.067	19.707	20-50	>3
	Pb	4.520	2.400	0.007	6.927	20-80	0.3-3

Notes: a) Same assumptions as used in Table 4.5-11.

b) As, Cu, and Pb total concentrations within the upper few inches of soil are assumed to be 974, 2237, and 565 µg/g respectively (extrapolated from Table 3-1, MultiTech 1984). Soil consumption values (per species) are the same as given in Table 4.5-11.

c) As, Cu, and Pb concentrations are assumed to be 38.3, 54.5, and 75.0 µg/g, respectively. The As data was taken from Formad 1908, p. 241 while the Cu and Pb data were composited from Dorn et al. 1975, Goodman and Roberts 1971, McGovern and Balsillie 1975, and Ragaini et al. 1977.

d) Taken from Table 4.5-11.

e) Represents the summation of the soil, food, and water dosages, per species-element contamination.

f) Acute and chronic toxicity values taken from Table 4.5-10.

A. DOCUMENT CONTROL FOR PROJECT (TITLE/NO.): Silver Bow Creek/Upper Clark Fork River Superfund Site

1. Sampling Date__/__/__; Weather Conditions:_____
2. Personnel Present: Crew Boss:_____; Others:_____
3. Reviewed By:_____ Assigned Document Control No._____ on __/__/__

B. LOCATION DATA

1. Ecological Response Unit or Soils Mapping Unit Code_____
   (Circle appropriate condition)

2. Site Location:
   State_____
   County_____
   Legal T____ R____ S____ Tract____
3. Photo-point Number_____; Topog. Map Name/Date_____
4. Plot/Site Sample Code_____Grid Loc. Code_____
5. General Site Description:_____
   _____
   _____

C. PHYSIOGRAPHIC/GEOLOGIC DATA

1. Physiographic Unit_____
2. Relief_____; Percent Slopes_____;
   Elevation (ft, msl)_____; Aspect_____
3. Geologic Parent Material:_____ known/presumed
   (Circle appropriate condition)
   Sample Taken? Yes/No Sample No._____
4. Soil Moisture/Temperature Regime (Climate)_____
5. Precipitation Zone_____, (Inches per Year).
6. Internal Drainage? Yes/No Drainage Conditions?_____

D. SOILS DATA

1. Soil Taxonomy_____;
   Soils Series/Association_____

Source: MultiTech

TABLE 4.5-13.--RECOMMENDED SOILS/CROPLAND SAMPLING SITE DESCRIPTION FORM

D. SOILS DATA (Continued)

2. General Properties:

Surface Soil Textural Class_____

Saline or Alkaline Surface Crust Present? Yes/No If Yes, describe

_____

_____

Coarse Fragments Present? Yes/No If Yes, describe_____

_____

Estimated Permeability (inches/hr.)_____

Effective Rooting (soil) Depth, inches_____

Groundwater Encountered? Yes/No If Yes, describe depth from surface, _____ inches.

Significance of Wind Erosion or Deposition_____

_____

Significance of Water Erosion or Deposition_____

_____

Soil Horizons Generally Moist or Dry_____

Other Appropriate Comments:_____

_____

_____

3. Profile Description (as appropriate)

Horizon	Depth (cm/in)	Bndry	Munsell Color; Dry/Moist	Texture	Structure	Consist.	pH	Roots

4. Soil Samples Taken? Yes/No If Yes, list sample number(s) by Horizon or Depth Increment:_____

_____

Source: MultiTech

FIGURE 4.5-13.--RECOMMENDED SOILS/CROPLAND SAMPLING SITE DESCRIPTION FORM (CONTINUED)

E. LAND USE/VEGETATION DATA

1. Present Land Use_____

2. Native Vegetation Present? Yes/No If Yes:

Predominant Species_____

_____

Estimated Percent Canopy Cover (total) and Bareground/Litter_____

_____

Presumed Climax Community or Habitat Type_____

_____

Vegetation Samples Taken? Yes/No If Yes, List Sample Number(s) by

Plant Species_____

_____

_____

3. Cultivated Lands Present? Yes/No If Yes:

Irrigated or Non-Irrigated (Circle appropriate condition)

Predominant Species_____

_____

Vegetation Samples Taken? Yes/No If Yes, List Sample Number(s) by

Crop Species_____

_____

4. Other Land Use Condition Wherein Samples Were Taken? Yes/No If Yes,

Record Sample Number(s) per Matrix Type_____

_____

5. List Any Other Land Use Condition or Type Wherein Samples Were Acquired:

Land Use Condition/Type; Matrix; Sample Number(s):_____

_____

6. Other Appropriate Comments or Observations:_____

_____

_____

Source: MultiTech

FIGURE 4.5.13.--RECOMMENDED SOILS/CROPLAND SAMPLING SITE DESCRIPTION FORM (CONTINUED)

F. ZOOLOGICAL DATA

1. Presence or Sign of Areal Utilization by Domestic Grazing Stock? Yes/No If Yes, Describe_____

2. Presence or Sign of Areal Utilization by Wildlife Species (especially Big Game Species and Species of Special Interest or Concern)? Yes/No If Yes, Describe_____

3. Other Appropriate Comments or Observations:_____

Source: MultiTech

FIGURE 4.5.13.--RECOMMENDED SOILS/CROPLAND SAMPLING SITE DESCRIPTION FORM (CONTINUED)

A. DOCUMENT CONTROL FOR PROJECT (TITLE/NO.): Silver Bow Creek/Upper Clark Fork River Superfund Site

1. Sampling Date__/__/__; Time___:___ (Military)
   Weather Conditions:_____
2. Personnel Present: Veterinarian_____
   Others:_____
3. Reviewed By:_____ Assigned Doc. Control No._____ on __/__/__

B. LOCATION DATA

1. Site Location:
   State:_____
   County:_____
   Legal: T____R____S____ Tract____
2. Photo-Point Number_____; Topog. Map Name/Date:_____/_____
3. Grid Loc. Code (x-y)_____; Livestock Owner/Address:_____
   _____
4. Species Present:___Dairy Cattle ___ Beef Cattle ___ Sheep ___ Horses ___ Swine ___ Poultry

C. MANAGEMENT HISTORY

1. Water Supply (Sources):_____
2. Feed/Forage Source(s):_____
3. Condition and Type(s) of Feed/Forage:_____
   _____
4. Method of Feeding:_____
5. Mineral Supplementation, Y/N:_____
6. Herd/Flock History:_____
   _____
7. Reproductive History
   % calf, foal, or lamb crop:_____
   Weaning weights (lbs):_____

TABLE 4.5-14.--RECOMMENDED FIELD WORKLOG FOR LIVESTOCK SAMPLING

Source: Adapted from Dollhopf et al. 1984 (pp. 50-51)

D. ANIMAL SAMPLING DATA

Sample Collection Tag No.	Animal ID No.*	Length of Residence	Age	Sex	Breed

* i.e., tag number attached to animal ear.

E. ADDITIONAL OBSERVATIONS/COMMENTS

1. Clinical Signs (of Poisoning):_____

2. Possible Cause (Tentative Diagnosis):_____

3. Supporting Evidence (e.g., poisonous chemicals, biological agents):

4. Recommended Treatment:_____

TABLE 4.5-14.--RECOMMENDED FIELD WORKLOG FOR LIVESTOCK SAMPLING (Continued)
Source: Adapted from Dollhopf et al. 1984 (pp. 50-51)

4.6 SUPPORTING FIGURES

No supporting figures are included.

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4.8 MAP POCKET